Popular Astronomy.

Vol. VII. No. 2. FEBRUARY, 1899. Whole No. 62.

THE EXTERIOR NEBULOSITIES OF THE PLEIADES.

H. C. WILSON.

Since the beginning of celestial photography the Pleiades group of stars has been one of the favorite objects of study by the new process. From the earliest long exposures of the extremely sensitive dry plates to this group came the discovery of curious wisps of nebulosity, arranged around and between the stars in such a way as to leave no doubt of their intimate connection with the stars. Some of these are well shown in Plate III, which is from a photograph taken at Goodsell Observatory on Jan. 30, 1894, and was published in the first volume of *Popular Astronomy*. Longer exposures seem to show that the whole group, excepting possibly Atlas and Pleione, the easternmost two bright stars, is involved in dense clouds of nebula. I have in hand a beautiful positive from a photograph taken in 1897 by Dr. Isaac Roberts with his 20-inch reflecting telescope, which shows the nebulous clouds with several times the density and greater extent than those shown in the plate. The negative was given an exposure of 10^h duration on the nights of Dec. 22, 23 and 25, 1897. A reproduction of it has been published in the *Monthly Notices* of the Royal Astronomical Society, May, 1898. The positive which Dr. Roberts has kindly sent me is much better than the reproduction in the *Monthly Notices* and shows many very faint outlying patches of nebula, which were printed out in the reproduction, tending to show that the nebula extends beyond the limits of the field of his photograph. I have since made an intensified copy of my 1894 negative which brings out all except the very faintest details of Dr. Roberts positive. A 16 hour exposure made with our 8-inch refractor in November, 1898, failed of its purpose because of the plate slipping in its holder, thus making all the star images double and the nebula correspondingly blurred, but it verifies many of the faint outlying patches in Dr. Roberts photograph.

In December, 1893, Professor E. E. Barnard, then at Lick Observatory, gave an exposure of $10^h\ 15^m$ to an 8x10 plate covering a field of over $10°$ diameter in the vicinity of the Pleiades,

using the Willard portrait combination of lenses of 6 inches aperture He obtained a negative showing extensive streams of very feeble nebulosity outside of the Pleiades group, but apparently connected with it, reaching outward to distances from 5° to 8° from the center of the group. These were "too vaguely shown upon the plate to make much out of" as Mr. Barnard said, but he had no doubt of their existence, having seen large nebulous areas in these regions many times while sweeping for comets with a small telescope.

In 1894 on the nights of Oct. 23, 24 and 25 I attempted to verify Mr. Barnard's work, giving a total exposure of $11^h\ 15^m$ to a Cramer Crown plate 8x10 inches, covering a field of 12° diameter. The camera objective used was a combination of four lenses of six inches aperture by Brashear, the curves having been calculated especially for stellar photography by Professor C. S. Hastings of Yale University. The focal length is 31 inches from the surface of the lens nearest the plate. This objective gives round star images over the whole field, the stars near the outer edge having greater diameters than those of the same brightness near the center, but not being otherwise distorted. The photograph obtained with this camera showed all the nebulous areas sketched by Professor Barnard and other fainter details between them, connecting them all together, but the image was so exceedingly faint that I did not then think it could be reproduced.

At the same time I exposed a 4x5 Seed nonhalation plate in a smaller camera, made up by myself, using a Darlot projecting lens which I found in our stock of physical apparatus. This lens defines fairly well over a field of 20° diameter. The plate exposed in this camera was probably over-exposed, since the sky-light comes out very strong without adding anything to the strength of the nebulous areas. The latter however are present upon the plate, having the same outlines as in the picture taken with the larger camera.

During the past summer, when on a visit to Professor Barnard at the Yerkes Observatory, I compared copies of these negatives with those obtained by him and we found that they agreed in almost every detail of the distant nebulous areas. It was therefore with considerable surprise that I read Dr. Robert's article in *Monthly Notices* June, 1898, received just when we were comparing the photographs, in which he claimed that those nebulosities were spurious, since he had given three exposures of 8^h, 9^h and 10^h, with a 5 inch lens and had not obtained any images of the exterior nebulous areas. I quote the following from Dr. Roberts' paper:

"The six photographs (three with the reflector and three with the 5-inch lens) which have been taken at my Observatory between 1897, Oct 8, and Dec. 1—a copy of the latter being here annexed—entirely discredit the existence of Professor Barnard's nebulosity. These photographs were taken with proper care; the star images are not distorted; there is no halation effect; the sky was clear during the various exposures of the plates, and the exposures were equal as regards photographic effect, for the stars and nebulosities shown on the plate with 10 hours are also shown on the 9^h and on that with 8 hours exposure."

All of which proves nothing, being only negative testimony. Dr. Roberts goes on to speak of the sources of defects in photographic plates, with which those who have had much experience in celestial photography are only too familiar, to their sorrow, and which have no bearing on the question so far as Professor Barnard is concerned, he having been a photographer from his boyhood.

In October and November, 1898, I attempted to still further verify the nebulas in question and to obtain negatives which could be reproduced. The plates used in October proved lacking in sensitiveness, but in November I succeeded in obtaining two negatives with the six inch camera and three with the 2½ inch lens all of which show the same nebulous areas. There are spurious nebulous areas also upon some of these plates but these are easily distinguished from the true ones by their varying positions upon the different plates.

From contact positives of these negatives, and those obtained in 1894 also, I have been able to make intensified negatives sufficiently strong to print upon silver paper. The two engravings in Plate II were made from silver prints from the central portions of the negatives taken in the six inch camera, and show fairly well the nebulous areas in dispute, although by no means as plainly as positives on glass from the same negatives. The scale is the same as that of the original plates.

No. 1 was exposed 4 hours on Oct. 23, 2 hours on Oct. 24 and $5^h\ 15^m$ on Oct. 26, 1894. This is the cleanest plate of those I have obtained, having almost no defects, and almost all the exterior nebulosity shown in the engraving is real. The bright spot in the center is the over developed image of the Pleiades group, the stars being hidden by both true nebulosity and atmospheric glare, i. e., the reflection of the light of the stars by particles of dust and frost suspended in the atmosphere. The plate was one of Cramer's most sensitive plates and was not

backed with anything to prevent halation. A large ring due to halation is seen around the stars Atlas and Pleione but there is little real nebulosity in this part of the group. The most noticeable of the exterior streams of nebulosity runs up from the right hand portion of the group half way to the top of the picture, then turns toward the left, extends horizontally past two bright stars, then toward the southeast half way to the letter *E*, where it spreads out into a large cloud near the left margin of the engraving. A fainter stream lies north of this, and between it and the Pleiades group is a mottled area full of details, vaguely shown but resembling those in the Orion nebula. All around the central group on the west and south are similar areas, and from the southernmost point of the Merope nebula a long stream sweeps toward the east a little more than half way to the margin, then turns toward the lower left hand corner. Another runs downward to the center of the lower margin of the picture. The right hand portion of the field was cut off partially by the too narrow shutter of the dome, so that but little extent of the nebula is seen in that direction. The length of the area of sky represented in this engraving is 7° and the width 5°.6.

The engraving No. 2, Plate II, is from a similar portion of a plate exposed for $5^h\ 35^m$ on the night of Nov. 15, 1898. The plate was a Cramer crown and was backed with a paste of lampblack, oil of cloves and turpentine, to prevent halation, so that there are no rings around the bright stars. The atmospheric glare is much less because of the shorter exposure also. The plate was developed to its utmost, at the risk of fogging, and there are some large light areas which are probably due to unequal sensitiveness of different parts of the plate. One of these is shown near the lower left corner of the engraving. The streams, however, which appear in No. 1, are seen in No. 2 with even greater intensity, except where they are masked by the defect referred to.

The other negative obtained with the 6-inch camera was on a Cramer crown plate exposed Nov. 10, 1898, $8^h\ 21^m - 13^h\ 21^m$, and Nov. 14, $9^h\ 55^m - 13^h\ 21^m$ Central standard time, making the total exposure $8^h\ 26^m$. This negative was not developed quite as far as it might have been, but it shows the same details as No. 1, with the addition (partial superposition) of a large approximately circular area, 6° or 8° in diameter, south of the Pleiades. This I take to be a result of the "Gegenschein" which I saw distinctly for the first time on the latter of these two nights. I do not speak confidently of this, and would not men-

tion it at all, except as a defect of the plate, but for the fact that similar and larger areas are noticeable upon the two plates exposed in the 2½-inch camera on the same two dates, the one on Nov. 10 from $8^h\ 21^m$ to $13^h\ 21^m$ and the other on Nov. 14 from $9^h\ 55^m$ to $13^h\ 21^m$. These areas are fully 10° in diameter and show an easterly motion of three or four degrees in the interval of four days. Their centers were approximately at R. A. 49°, Decl. + 19° on Nov. 10 and R. A. 53°, Decl. + 19° on Nov. 14, but the determination of the center of such an extremely vague object must be very uncertain. On Nov. 15 I estimated the center of the Gegenschein, as I saw it visually, to be 5° directly south of the western end of the Pleiades group. This would place it at R. A. 54°, Decl. + 19°, agreeing with the potographs, but 3° in advance of the point opposite the Sun, instead of lagging behind as it should according to previous observers. The photograph taken Nov. 15 with the 2½-inch camera was fogged by light getting into one corner of the camera, so that it is valueless on the question of the Gegenschein, although it shows traces of a round luminous area on the unfogged portions, and several of the nebulous clouds near the Pleiades are plainly visible.

I do not, however, wish to make any point on the Gegenschein without further investigation. I only wish to emphasize the fact that fainter light than that of the exterior nebulosities of the Pleiades has made its impression upon my plates. Of the latter, there can be no question. On three of my photographs, taken with the 2½ inch camera, all of the nebulosities sketched by Mr. Barnard, in his diagram in *Astronomische Nachrichten*, No. 3253, are shown in the same positions, with practically the same outlines, and the spaces between them are filled in more or less with nebular light, which connects them together, and indicates that they are probably parts of one great nebula, at least 8° long, east and west, by 6° wide.

These nebulous areas can be photographed with only moderately long exposures, provided the plates be sensitive enough and the sky clear enough. My best photograph with the 2½-inch camera is that having the shortest exposure, only $3^h\ 30^m$. This plate, as well as the others, also shows a large nebulous area south and west of ζ and o Persei and another north of ξ Persei. The latter must be very bright because it shows plainly, although it is close to the edge of the field, where the light is much reduced.

Comparing my photographs with a positive, which Dr. Rob-

erts has kindly sent me of his 10^h exposure with the 5-inch camera, I can see traces of the brighter nebular streams on his own photograph, where he says there is nothing but spurious nebulosity. This positive also reveals plainly the reason why Dr. Roberts has failed to get more than the merest traces of the disputed objects. The atmospheric glare around his star images is something tremendous when compared with that on our plates. The Pleiades group is completely blotted out, not even Atlas and Pleione showing, nor the notch between these stars and the Merope nebula, which shows so plainly in both the engravings in Plate II. Many of the fainter stars outside the group also have quite large atmospheric halos around them, while in our plates not a single star outside the group possesses such a halo. This shows that our atmosphere must be much clearer than that in which Dr. Roberts works, for he states that the photographs in question were taken on very clear nights.

The photographs at Northfield were taken on nights when the air was very transparent, after days when the Sun showed but the slightest trace of haze around it, and one could look almost up to the very edge of the solar disk without protecting the eye. Such days are quite common here in the autumn and winter, and the pity is that from lack of funds and of time from other than astronomical duties we cannot utilize more of them.

THE ROTATION OF THE SURFACE OF THE PLANET JUPITER.

G. W. HOUGH.

For Popular Astronomy.

During the past twenty years a great many observations have been made to determine the rotation period, due to spots and markings on the surface of the planet Jupiter. Although many interesting facts have been established, yet a good deal remains to be investigated relative to the changes taking place on the surface of the planet.

The statement is generally made, and is found in some recent text-books on Astronomy, that the surface rotation is similar to that of the Sun, being quickest near the equator and slowest in higher latitudes.

In the Annual Report of the Chicago Astronomical Society for 1882, I wrote as follows: "It is possible, however, that the rotation of the surface varies with the latitude, in a manner analogous to the Sun's surface."

PLATE III.

PHOTOGRAPH OF THE PLEIADES.

Taken at Goodsell Observatory, Jan. 30, 1894, by H. C. Wilson.

Exposure 4^h

The rotation periods determined in subsequent years do not confirm the assumption. I think there is some misconception regarding the actual phenomena in question. There are two principal rotation periods, $9^h\ 50^m$ to 51^m and $9^h\ 55^m$ to 56^m, due, I imagine, to the matter under observation, being located in separate envelopes or strata; the spots and markings giving the shorter period being the most elevated.

Now, the longest period is not confined to the higher latitudes, nor the shortest period to the equatorial regions. In fact, the two periods have been found in approximately the same latitude, but usually the shortest period is confined within $\pm\ 3''$ of distance from the equator or Jovicentric latitude $\pm\ 9°$.

The following table of rotation periods will elucidate the subject. Unless otherwise stated, the rotation periods have been derived from numerous observations extending over a considerable interval of time. The observations, on which the following results are based, may be found in the Annual Reports of the Chicago Astronomical Society, 1880 to 1887; *Monthly Notices* of the Royal Astronomical Society, Vol. 51, No. 6, and in the *Astronomishe Nachrichten*, No. 3354, with the exception of the years 1896-7-8, which as yet are unpublished.

The first column of the table is the year; 2nd, the kind of marking observed; 3rd, distance from the equator in seconds of arc; 4th, the approximate Jovicentric latitude; 5th, rotation period. The distance from the apparent equator has been reduced to "mean" distance and corrected for the elevation of the Earth above Jupiter's equator, and is designated reduced latitude. For convenience of comparison, I have tabulated the results according to the Jovicentric latitude.

The white spots, observed in the higher latitudes, were usually elliptical, the major axis lying in the direction of rotation. They were about $1''$ of arc in length and measures of precision could only be made under favorable atmospheric conditions.

An examination of the following table shows that the rotation period $9^h\ 55^m +$ is not connected by any simple law with the latitude. In 1891, in Jovicentric Latitude $-\ 25°$ to $-\ 28°$, 3 spots observed over a long interval gave respectively $9^h\ 55^m\ 20^s.0$, $03^s.0$, $20^s.0$ and in 1896-7-8, a spot in Latitude $+\ 24°$ to $+\ 21°$ gave $9^h\ 56^m\ 00^s.4$, $55^m\ 59^s.7$ and 52^s, respectively. The mean of the two determinations are nearly the maximum and minimum values for the principal rotation period $9^h\ 55^m +$ and, although in opposite hemispheres, they occupied nearly corresponding parallels.

Date.	Name.	Red-Lat.	Approx. Jovicentric Latitude.	Rotation Period.			
		″	°	h	m	s	
1880	white spot	+ 11.4	+ 37	9	55	39.3	
"	black spot	+ 11.3	+ 37			31.0	
"	black spot	+ 10.6	+ 34			35.1	
1896	Black B_3	+ 8.4	+ 26	9	56	00.4	Observed 168 days
1897	" "	+ 8.2	+ 25	9	55	59.7	" 46 "
1898	" "	+ 7.9	+ 24			52.	" 58 "
1891	Black spots (B_3)	+ 6.6	+ 20	9	52	Approx.	
1890	(5 spots)	+ 4.8	+ 14	9	55	32.0 to 36.6	
1891	2 spots	+ 4.7	+ 14			27.4	
1895	Black spots	+ 4.7	+ 14	9	55	22.8	
"	"	"	"			30.0	
"	"					36.6	
"	"	"	"			38.1	
"	"	"	"			49.1	
"	"	"	"			34.2	
1895	White spots	+ 4.7	+ 14	9	55	23.2	
"	"	"	"			38.1	
"	"	"	"			38.4	
"	"	"	"			36.0	
"	"	"	"			44.2	
"	"	"	"			25.4	
1898	Black spot	+ 4.4	+ 13	9	55	27	Observed 191 days
"	"	+ 4.4	+ 13			24	" 132 "
1882	White spot	+ 3.7	+ 11	9	49	33	
1891	"	+ 2.7	+ 8	9	50	31.6	
1884	"	+ 1.3	+ 4	9	50	09.2	
1880	"	− 1.3	− 4	9	50	00.6	
1883	"	− 1.3	− 4	9	50	12.7	
1880	"	− 1.8	− 5	9	50	09.8	
1881	"	− 2.1	− 6	9	50	09.8	
1891	"	− 2.0	− 6	9	50	26.4	
1884	"	− 2.7	− 8	9	50	09.8	
1880	Spur on edge of						Rotation
1881	Eq. belt	− 4	− 12	9	55	37	Same as Great Red Spot
1883							
to	Depression in						Rotation
1899	Eq belt.						Same as Great Red Spot
1879	Great Red Spot	− 6.3	− 19		55	34.0 to 41.8	
to							
1898							
1884	White spots.	− 6	− 18	9	55	43.8	
"	"	− 6	− 18			43.3	
1891	Long red	− 8.34	− 25	9	55	20.0	
"	"	− 8.24	− 25			03.0	
1881	White	− 8.7	− 27	9	55	37	
"	"	− 8.7	− 27			17.6	
"	"	− 8.7	− 27			23.8	
1883	"	− 9.0	− 28	9	55	37	
1891	Black	− 9.0	− 28	9	55	20.0	
1883	"	− 9.4	− 29	9	55	37	
1886	"	− 9.7	− 31	9	55	30	
1880	"	− 10.7	− 34	9	55	31.0	
"	"	− 10.7	− 34			33.6	
1881	"	− 11.7	− 38	9	55	35.5	

From detached spots and markings, it is seen that the rotation period $9^h\ 55^m$ + approaches within 13° of the equator. The great equatorial belt, both on its north and south margins,

gives a rotation approximately the same as the great red spot, and I believe the great mass of the belt within 5° of the equator rotates with the same velocity.

During the past twenty years the outer edges of the belt have approached within a distance of 3″ from the equator. This brings the rotation period $9^h\ 55^m +$ within 9° of the equator. According to the table of results, the shorter rotation period $9^\circ\ 50^m +$ extends from + 11° to — 8° Jovicentric latitude. The abnormal period $9^h\ 52^m$, observed in 1891, was derived from micrometrical measurement on three spots on two successive days only. The individual spots in the order of longitude gave, respectively, $9^h\ 51^m\ 20^s.7$, $52^m\ 06^s.0$ and $52^m\ 30^s.0$. There was a large group and it was difficult to identify individual spots. Mr. Denning, observing over an interval of 25 days, derived a mean period of $9^h\ 49^m\ 27^s$. (*Observatory*, No. 180.)

The apparent rotation period is not constant for a spot in any latitude, even during one opposition. Usually when two or more spots are in close proximity, they shift in longitude with regard to each other. I showed in 1880 that the observations of the great red spot during a single opposition could only be satisfied by making the rotation period a function of the time; and subsequently found it to be true for all spots and markings on the surface of the planet.

There does not seem to be any well established law for motion in different latitudes. In fact, our material is as yet too meagre to draw general conclusions. The drift of the surface material, in latitude, which has scarcely been studied, I consider quite as important as the drift in longitude.

In a number of previous papers I have called attention to the fact that the Jovicentric or Jovigraphic latitude conveys no definite idea as to the position of the object on the disk, and it is necessary to reconvert it into seconds of arc, or parts of the polar diameter of the planet in order to locate it. The latitude is a scale of unequal parts and no one can estimate it even approximately. The latitude is not needed for the study of motion on different parts of the disk. In any case, the estimated, or measured distance from the apparent equator of the disk, should be given if observers insist on giving the latitude in degrees. It is just as convenient to apply the correction for the elevation of the Earth above Jupiter's equator, to the measured distance as to the apparent latitude.

The following equations give the Jovicentric latitude in terms of the distance from the equator and the reverse:

$$\tan \varphi = \frac{b}{a} \cdot \frac{y}{\sqrt{(b+y)\,(b-y)}}$$

$$y = \frac{ab \tan \varphi}{\sqrt{a^2 \tan^2 \varphi + b^2}}$$

φ = Jovicentric latitude.
a and b = Semi-axes of the disk.
y = distance from the equator.

DEARBORN OBSERVATORY OF NORTHWESTERN UNIVERSITY,
Jan. 11, 1899.

WITT'S PLANET, (433) DQ.

EDWARD C. PICKERING.

A careful search has been made by Mrs. Fleming upon the Harvard plates for early photographs of Witt's Planet, (433) DQ. Mr. S. C. Chandler has courteously furnished ephemerides based upon the best available material, and has devoted much time to correcting the elements and computing the positions corresponding to the times at which certain photographs were taken, as is more fully explained in the *Astronomical Journal*, No. 452.

In making this search the following method of procedure has been adopted. Mr. Chandler, by means of the elements published in the *Astronomical Journal*, No. 451, computed ephemerides for the oppositions of 1894 and 1896. It appeared that the observations then available were insufficient to determine the position in 1894. An error of 1″ in the mean daily motion in the orbit would change the right ascension of the object in 1894 by about half an hour. Moreover, the value of the daily motion differed by several seconds not only in the early ephemerides of this planet, but in those dependent on a large number of visual observations. Although plates were examined by Mrs. Fleming, covering a region of about 1300 square degrees, the planet was not found. Plates taken in 1896 were next examined, as it was thought that the smaller errors of the ephemeris would compensate for the extreme faintness of the planet. This examination proved to be especially laborious and fatiguing to the eyes. It was feared that the object might be too faint to appear upon the plates and accordingly the faintest objects were carefully scrutinized.

Each plate was examined by superposing it upon another plate of the same region taken with the same instrument. Two adjacent images then appeared of each star, while the planet, if

present, would appear only upon the upper plate. Numerous suspicious objects were thus found including several images of the planets Flora (8) and Nysa (44), and two new variable stars, whose approximate positions for 1900 are in R. A. 8^h $33^m.9$, Decl. $+ 50° 29'$, and R. A. 18^h $38^m.7$, Decl. $- 38° 52'$, were discovered. The star $+ 29°.551$ fails to appear on ten plates which show other faint Durchmusterung stars, and two stars at R. A. 9^h $11^m.4$, Decl. $- 10° 43'$ and R. A. 9^h $11^m.5$, Decl. $- 10° 16'$ appear upon the Durchmusterung charts and upon the photographic plates, but are not given in the Durchmusterung catalogue.

At last a faint image was found on a plate taken on June 5, 1896, and confirmed by other plates taken on June 4 and June 5. A plate taken on April 6 covered the region of the planet which was readily found by means of its computed position. Mr. Chandler, from positions of these images, was enabled to furnish a corrected ephemeris for 1894, by means of which the planet was readily detected on several plates. The positions so far found are given below. The successive columns give the number of the plate, the date, the Greenwich Mean Time of the middle of the exposure, the length of exposure in minutes, the approximate right ascension and declination for 1875, and the number of comparison stars used in the determination of the position. The instrument used is indicated by the letter in the first column, A denoting the 24-inch Bruce telescope which was then in Cambridge, B the 8-inch Bache telescope in Arequipa, and I the 8-inch Draper telescope in Cambridge. The method of measurement is that described in the Harvard Observatory Annals, Vol. XXVI, p. 228.

Plate.	Date.			G. M. T.		Ex.	R. A. 1875			Decl. 1875.			Comp.
	y	m	d	h	m	m	h	m	s	°	′	″	
I 10215	1893	12	19	18	21	14	7	45	57.0	+ 54	38	41	5
"	1893	12	19	18	21	14	7	45	57.5	+ 54	38	37	5
I 10321	1893	12	27	17	32	10	7	44	43.2	+ 50	54	45	6
"	1893	12	27	17	32	10	7	44	42.8	+ 50	54	43	6
I 10353	1894	1	1	17	09	59	7	41	34.5	+ 47	54	±	7
A 246	1894	2	16	14	49	12	7	29	58.3	— 0	21	45	11
"	1894	2	16	14	49	12	7	29	58.1	— 0	21	41	11
B 10909	1894	4	16	14	13	10	9	17	0 ±	— 13	34	15 ±	7
B 10951	1894	4	18	14	29	10	9	21	48 ±	— 13	39	1 ±	7
B 15531	1896	4	6	20	52	60	18	37	0.3	— 38	32	51	6
"	1896	4	6	20	52	60	18	37	0.5	— 38	32	48	6
B 16108	1896	6	4	16	40	70	18	30	5.3	— 40	2	46	9
B 16157	1896	6	5	19	54	10	18	27	51.0	— 39	58	17	9
B 16165	1896	6	5	22	04	11	18	27	39.1	— 39	57	53	9
"	1896	6	5	22	04	11	18	27	39.7	— 39	58	8	9

I 10321. Image 4° from center of plate and therefore distorted, but shows direction of motion.

I 10353. Spectrum plate showing that the spectrum of this object, like that of the other planets and of the Sun, is of the second type.

A 246. Image much distorted and elongated.

B 16108. Image much elongated owing to rapid motion.

B 16157. Image very faint, near edge of plate and therefore much distorted, but shows motion by comparison with B 16165.

The following ephemeris and elements have been computed by Mr. Chandler, by combining the observations of 1898 with those derived from the photographs taken December 19 and 27, 1893, February 16, 1894, April 6, 1896, and June 4 and 5, 1896.

EPHEMERIS FOR GREENWICH MIDNIGHT AND EQUINOX OF 1894.0.

Date. 1893.	R. A 1894.0 h m s	Decl. 1894.0 ° ′	v	log r	log Δ	Magn.
Oct. 27.5	5 56 22	+ 53 18.6	− 71 28.3	0.1120	9.6713	9.86
31.5	6 8 15	54 15.0				
Nov. 4.5	6 20 3	55 4.8	− 65 49.4	.1038	.6254	9.59
8.5	6 31 39	55 49.6				
12.5	6 43 0	56 28.4	− 59 57.6	.0958	.5778	9.31
16.5	6 53 56	57 0.4				
20.5	7 4 18	57 25.1	− 53 52.8	.0881	.5285	9.02
24.5	7 13 59	57 41.3				
28.5	7 22 48	57 47.9	− 47 35.4	.0809	.4772	8.73
Dec. 2.5	7 30 29	57 43.8				
6.5	7 36 54	57 27.4	− 41 5.7	.0743	.4240	8.43
10.5	7 41 52	56 56.6				
14.5	7 45 19	56 8.8	− 34 24.6	.0684	.3692	8.13
18.5	7 47 15	55 1.5				
22.5	7 47 41	53 31.0	− 27 33.4	.0634	.3141	7.83
26.5	7 46 44	51 34.2				
30.5	7 44 37	49 7.4	− 20 33.5	.0594	.2615	7.55
1894.						
Jan. 3.5	7 41 34	46 7.8				
7.5	7 37 59	42 34.5	− 13 26.9	.0565	.2170	7.31
11.5	7 34 15	38 28.9				
15.5	7 30 45	33 55.4	− 6 15.8	.0548	.1890	7.16
19.5	7 27 46	29 1.3				
23.5	7 25 30	23 58.6	+ 0 57.5	.0543	.1850	7.14
27.5	7 24 6	19 0.1				
31.5	7 23 34	14 15.9	+ 8 10.5	.0552	.2065	7.25
Feb. 4.5	7 24 0	9 55.0				
8.5	7 25 20	6 1.3	+ 15 20.7	.0572	.2475	7.47
12.5	7 27 37	+ 2 37.3				
16.5	7 30 46	− 0 18.0	+ 22 25.7	.0604	.2994	7.74
20.5	7 34 41	2 46.8				
24.5	7 39 17	4 51.6	+ 29 23.5	.0647	.3551	8.04
28.5	7 44 31	6 35.4				
Mar. 4.5	7 50 20	8 1.0	+ 36 12.1	.0699	.4111	8.35
8.5	7 56 41	9 10.7				
12.5	8 3 32	10 8.5	+ 42 50.3	.0760	.4654	8.65
16.5	8 10 48	10 55.3				
20.5	8 18 29	11 33.2	+ 49 16.8	.0828	.5175	8.94
24.5	8 26 30	12 4.0				
28.5	8 34 50	12 29.1	+ 55 30.9	.0901	.5672	9.23
Apr. 1.5	8 43 25	12 49.3				
5.5	8 52 15	13 5.8	+ 61 32.2	.0979	.6147	9.50
9.5	9 1 18	13 19.6				
13.5	9 10 34	13 31.3	+ 67 20.6	.1059	.6604	9.77
17.5	9 19 59	13 41.8				
21.5	9 29 33	− 13 51.7	+ 72 56.1	0.1142	9.7043	10.03

The brightness for 1898, Aug. 24.5 is taken as 11.5 ($\log r = 0.2396$, $\log \Delta = 9.8722$).

ELEMENTS.

Epoch 1898, Aug. 31.5, G. M. T.
$M = 221° 35' 45''.6$
$\omega = 177\ 37\ 56.0$
$\Omega = 303\ 31\ 57.1$ } 1898.0.
$i = 10\ 50\ 11.8$
$\varphi = 12\ 52\ 9.8$

$\mu = 2015''.2326$
$\log a = 0.1637876$
Period $= 643^d.10$

A comparison of the observed positions with those obtained by computation is given below. The successive columns contain the date, the Greenwich mean time, the apparent right ascension and declination, and the corrections to the ephemerides published in the *Astronomical Journal*, and that given above. The approximate value of the true anomaly is given in the last column.

Date.			G. M. T.		Apparent R. A.			Apparent Decl.			O − C R. A.	O − C Decl.	O − C′ R. A.	O − C′ Decl.	v
y	m	d	h	m	h	m	s	°	′	″	m s		s	′	°
1893	12	19	18	21	7	47	29.4	+54	35	50	.....	.....	+3.5	0.0	−30
	12	27	17	32	7	49	11.3	+50	51	57	.....	.....	−0.7	−0.3	−23
1894	1	1	17	09	7	42	59.8	+47	31	±	.....	.....	−1.9	−1.0	−19
	2	16	14	49	7	39	57.8	− 0	24	9	.....	.....	+5.1	−1.0	+22
	4	16	14	13	9	17	54.0	−13	39	16	.....	.....	+7.6	+0.2	+69
	4	18	14	20	9	22	42.6	−13	42	2	.....	.....	+7.4	+0.4	+71
1896	4	6	20	52	18	38	30.1	−38	31	42	− 0 39.0	− 4.8	+3.0	+1.3	+115
	6	4	16	40	18	31	37.4	−40	01	52	− 1 16.7	− 5.9	+0.9	+1.5	+142
	6	5	19	54	18	29	23.1	−39	57	28	− 1 16.4	− 5.6	+1.2	+1.8	+142
	6	5	22	04	18	29	11.5	−39	57	11	− 1 16.7	− 5.8	+0.9	+1.7	+142

The residuals $O - C'$ show that the object on each plate was surely the planet. They by no means represent the accuracy to be expected, either in computation when the perturbations of the Earth are included, or in measurement when time permits the use of more precise methods. Images have since been found on plates taken November 26 and December 23, 1893, and January 19, January 25, January 30 and February 5, 1894.

HARVARD COLLEGE OBSERVATORY, Circular No. 36.
December 26, 1898.

ADDITIONAL OBSERVATIONS OF EROS, (433).

The method of search for Eros, (433), described in Circular No. 36, has been continued. The ephemeris has been extended by Mr. Chandler, as required, and images of the planet have been found by the writer on thirteen plates. From these images the following approximate positions have been determined in addition to those given in Circular No. 36. The successive columns give the number of the plate, the date, the Greenwich mean time of the middle of the exposure, the length of the exposure in minutes, and the approximate right ascension and declination for 1875. These positions are, in general, derived from adjacent Durchmus-

terung stars. Preparations are now being made for precise determinations of the positions of the planet on these plates, and on those described in Circular No. 36. The last two columns give the anomaly and the computed photographic magnitude, assuming the magnitude at distance unity, 12.0, as derived from the measures given in Circular No. 34. The correction for phase is necessarily omitted, and may exceed a magnitude, as the phase angle may amount to 60°. The last three plates were taken at Arequipa, all of the others at Cambridge.

Plate.	Date.			G. M. T.		Ex.	R. A. 1875.		Dec. 1875.		v.	Magn.
	y	m	d	h	m	m	h	m	°	′	°	
I 9801	1893	10	28	21	55	14	5	58.8	+ 53	40	− 71	10.9
I 9832	1893	10	30	20	18	10	6	4.5	+ 54	6	− 69	10.8
I 9862	1893	10	31	21	21	15	6	7.6	+ 54	20	− 69	10.8
I 10095	1893	11	26	20	26	17	7	17.5	+ 57	50	− 49	9.9
I 10280	1893	12	23	19	49	13	7	45.7	+ 52	58	− 26	8.8
I 10407	1894	1	8	18	8	65	7	35.5	+ 41	23	− 12	8.4
I 10469	1894	1	19	16	57	10	7	26.5	+ 28	46	− 3	8.2
I 10559	1894	1	25	16	16	13	7	23.6	+ 21	15	+ 3	8.2
I 10604	1894	1	30	13	40	60	7	22.5	+ 15	20	+ 7	8.3
A 222	1894	2	5	15	26	60	7	23.3	+ 8	46	+ 12	8.4
B 11174	1894	5	19	14	16	10	10	38.0	− 14	57	+ 92	11.9
B 16518	1896	6	29	19	17	15	17	37.8	− 36	22	+152	12.5
A 1876	1896	6	30	13	46	61	17	36.4	− 36	12	+152	12.5

I 9801. This photograph is important since with that taken on May 19, 1894, the anomaly through which the planet was observed in 1893-1894 becomes 162°. The observations contained in Circular No. 36 extended over an angle of 101°.

I 10280. Plate dark, and difficult to measure.

I 10407. Faint spectrum on edge of plate.

I 10469. This plate was fogged and was so dark that it was marked useless. Its density was about that of a shade glass used in viewing the Sun. By making a double contact print from it a photograph is obtained on which accurate measurements of the planet are possible.

I 10604. Spectrum. Superposed on spectrum of + 15°.1581, Magn. 9.5.

A 222. Well marked trail 160″ long, showing irregularities in running of driving clock of telescope.

B 11174. See I 9801.

A 1876. Well marked trail. At about $13^h\ 15^m$ the planet would have coincided very nearly with − 36°.11846. The orbit of the planet could be well determined from the observations in 1896 alone, using for the first place the position of April 6, for the second the three positions on June 4 and June 5, given in Circular No. 36, and for the third, this photograph with that taken on June 29.

Some important conclusions may be derived from this investigation. All the photographs on which the planet has been found were taken with doublets. If they had been taken with lenses of the usual form with a field 2° in diameter all of the images would have fallen outside of the plates. In view of the difficulties found in photographing this object with an ordinary lens at Greenwich and Oxford (*Observatory* XXI, 429) it is doubtful whether we should have obtained many images of it here with such a lens, even if it had been in regions photographed. The number of plates on which the planet appears probably fairly represents the number we have of all other similar objects whether already discovered or not. This planet is bright during only a small portion of time. During the last eleven years it has been brighter than the ninth magnitude, photographically, for only two months, or about a seventieth part of the entire time. There may be other similar objects, even brighter, as yet undiscovered. Nova Aurigæ was as bright as the fifth magnitude for six weeks before it was discovered. Had Eros attained the sixth magnitude instead of eighth it should have appeared on plates taken with the transit photometer. In this case, we should have had an image of it on every clear night on which it culminated after dark. Fairly good positions could have been obtained from these images since the focal length of the telescope is about two feet, and the exposures are so short that the images are always circular. We have now a similar instrument in Arequipa so that in general two images should be obtained every night.

HARVARD COLLEGE OBSERVATORY, Circular No. 37.
January 16, 1899.

NOVEMBER METEORS.

W. A. COGSHALL.

FOR POPULAR ASTRONOMY.

The shower of Leonids of November last was observed at the Lowell Observatory on the nights of the 13th and 14th. The observations were of two kinds—first, to determine the time of the maximum display, and second, to obtain, if possible, some reliable parallaxes. The former observations were carried on by Mr. S. L. Boothroyd, of this Observatory, assisted on the first night by Mr. McCurty of Flagstaff. The observations were confined to an area of about 40° in diameter, having the radiant point as a center. The results are tabulated as follows:

Nov. 13. h h	Number Counted.	Remarks.
13 — 14	8	
14 — 15	12	
15 — 16	10	
16 — 17	7	In alternate periods of 10^m each.
17 — 18	6	" " " " " "

About twenty more were counted which were outside the given region. Most of the magnitudes were rated at three and four, but at about 16^h 25^m a bright meteor was seen in the south-east which was brighter than Venus at her best.

On the next night the results were as follows:

Nov. 14. h h	No. Counted.	Outside Region.	Remarks.
12 — 13	3	1	
13 — 14	22	6	
14 — 15	26	3	
15 — 16	29	6	
16 — 17	6	8	Observations each alternate 10^m.

From this it appears that the maximum of the shower was Nov. 14 between 15^h and 16^h. Twenty-five of these paths were traced on star maps and are included in the determination of the radiant point.

The other observations on Nov. 14 were made at two points, the dome of the Observatory in Flagstaff and a point about fifteen miles to the north-east near Turkey Tanks. At the latter place Mr. Godfrey Sykes and Mr. H. Hussey, of Flagstaff, traced on a star map, enlarged from the charts of R. A. Proctor, the trails of as many of the brighter meteors as they were able, accurate time being taken for each, and at the Flagstaff station Mr. D. A. Drew and the writer did the same. In this way each party charted the paths of about twenty-five meteors. On account of the generally short trails and the faintness of nearly all the meteors only six coincidences in time of recording a meteor were found and of these only one, No. 6, observed at 23^h 07^m G. M. T. gives a satisfactory parallax. The six meteors seen from both stations may be tabulated as follows:

No.	Height. Upper end. miles.	Lower end. miles.	Remarks.
1.			Parallax negative. Large errror in locating on map.
2.	279.3	407.0	Error in direction on map. Trails short.
3.			On edge of map. No stars to locate it by. Large error.
4.	1861.	172.2	
5.	297 0	88.0	
6.	52.5	25.7	

The reductions were made by means of the "Astronomer's Globe," a description of which, by Mr. A. E. Douglass, will be found in POPULAR ASTRONOMY, No. 42, 1897. In this case the

globe was set with the sidereal time of observation on the meridian and the trails traced on the globe in their observed positions. As seen by Mr. Sykes the trails were generally shorter than those recorded at Flagstaff, which is partially accounted for by the fact that he and Mr. Hussey had a large fire near by as the night was cold and windy. To allow for this the Flagstaff trails were shortened at each end to make them the same length as observed by Mr. Sykes. By setting the horizontal circles of the globe at 71°.4 from the north toward the east (the azimuth of the other station from Flagstaff), the direction in which parallax would occur is at once found, and by swinging the western half of the circle up to the position of the trails on the surface of the globe, the angles of the triangle between the two stations and the meteor, and the altitude as seen from each place are at once read off.

Observations of the Leonids Nov. 13 and 14, 1898, at Turkey Tanks and Flagstaff, Arizona.

In the case of meteor No. 6, the difference in the angles measured along the great circle connecting the two stations, or the angle of parallax, was 5°.0 for the upper ends of the trails, and 7°.0 for the lower ends. This, when reduced, gives a perpendicular distance above the Earth's surface of 58.5 miles for the first appearance of

the meteor, and 25.7 miles for the place where it disappeared, a result well within the range of possibility but for which no claims can be made as regards exactness. For it is evident that by the method employed, without great experience and care on the part of the observers, there will be a probability of errors so great as to almost destroy the value of the results obtained.

Errors would also be lessened if the base line were in a north and south direction, as suggested by Professor W. H. Pickering and somewhat longer than we used. By force of circumstances ours was nearly east and west and rather too short. For an east and west line the distance should be probably 40 miles or more; and for a north and south line a distance of at least 30 miles should be used.

All the charted paths have been included in the map herewith presented for a determination of the radiant, but the paths of non-Leonids, or of those, which, for any reason, are manifestly in error are not produced backward to determine a radiant point. The position as given by these trails covers an area of about 5°. in diameter, with its centre at $9^h\ 56^m$ right ascension, and + 20° declination. It may be of interest to those who are working in this line to know that an old resident of Arizona relates having seen a brilliant shower of meteors in the early morning sometime between Nov. 16 and 19, 1892. At that time he was camped with a party a few miles north of Phoenix.

It is to be hoped that the next return of the Leonid shower will give us more results in this direction, and with a greater number of meteors, careful observers and good weather there is no reason why some good results may not be obtained.

LOWELL OBSERVATORY, Flagstaff, Arizona.

A SUMMARY OF PLANETARY WORK AT THE LOWELL OBSERVATORY AND THE CONDITIONS UNDER WHICH IT HAS BEEN PERFORMED. *

A. E. DOUGLASS.

In accordance with the title, the present paper divides itself into two parts, of which the first will be a brief *resumé* of the planetary work done here, with a few details and announcements which have not heretofore been given to the public, and the second will present the writer's personal opinions of why it has been possible

* Presented at the Boston meeting of the A. A. A. S., August, 1898.

to reach these results. The latter must necessarily be more in the form of suggestions than facts, for to give facts one must have tried personally many widely separated localities over long periods of time.

Mercury was observed in the summer of 1896 immediately after work was begun with the 24-inch telescope. The observations were made by Mr. Lowell, assisted by Mr. Drew. Lines of various widths were seen and Schiaparelli's result was confirmed, that Mercury rotates once in its revolution about the Sun. Mr. Lowell describes the appearance of the planet as a chiaroscuro of black and white resembling the Moon or the satellites of Jupiter, more than planets holding atmospheres, such as Mars or Venus. He likens the dark markings to the areas on the Moon, known as seas.

Venus was observed at the same time by the same two observers and was also found to present continuously the same face towards the Sun. This result had been obtained by Schiaparelli and others, with less certainty than in the case of Mercury and had been most earnestly disputed by many other observers, so that Stanley Williams in 1893 considered the balance of evidence in favor of the 24 hour period. Mr. Lowell describes the markings on Venus as faint but yet readily seen on a reasonably good day. He made a good map of the planet. A straw color overlies the planet which he attributes to its atmosphere. He thinks there are few mountains. As there seem to be no indications of water vapor on the illuminated side, he argues that if such exists on the planet, it must have all passed to the night side and been deposited in the form of great ice sheets, leaving the bright side a complete desert. Mr. Lowell attributes his ease in seeing these markings to good atmosphere, daytime observations, and low powers; he also used colored glasses. The writer's experience has been that he never saw these markings with satisfaction until small apertures, from 2 to 5 inches, were tried. Certain lines were then unmistakable and were readily seen under varying conditions, such as different lenses, apertures, eye-pieces, position of eye, etc.

Mars, during its favorable season, has been a special object of attention. In 1894 Mr. Lowell found in its light regions a large number of new canals, and greatly increased the known number of lakes and oases, first recognized by Professor W. H. Pickering at Arequipa in 1892. His other most important work in 1894, was in tracing the seasonal changes taking place on the planet,

facts which have the most direct bearing on its physical condition and its adaptability to habitation. The south pole of Mars was at that time towards us, and the south polar cap was observed to diminish as the Sun crossed the Martian equator toward it. The cap disappeared shortly after the equinox. Simultaneously with the diminution of the cap a dark line formed about it and the tint of the grey areas of the south temperate zone deepened to a beautiful bluish-green, directly suggesting vegetation. This darkening travelled progressively toward the north, reaching eventually in the northern hemisphere almost to the Arctic circle. Meanwhile the large southern bluish-green areas turned a distinct brown and finally after the complete melting of the polar cap faded to a slowly lightening yellow. All this is highly indicative of vegetation and its importance cannot be overestimated.

While Mr. Lowell was carrying on these observations Professor W. H. Pickering succeeded in detecting polarization in some of the larger markings bordering the melting cap but found none in the other large dark markings, an indication that the former are liquid and that the latter are not. And at the same time the writer discovered that all the dark patches in the southern hemisphere consist of a net-work of canals precisely similar to those in the northern hemisphere, save that the intervening spaces are filled with apparently the same coloring matter that gives the dark tint to the canals. "Dark-region canals" had been seen in succession by Professor W. H. Pickering, the writer and Professor J. M. Schaeberle, in 1892 but their character was not definitely decided upon.

Another investigation was persued by him, namely of the projections and depressions observed on the terminator. A study of over 700 of these irregularities led to the conclusion that the projections are due to clouds and depressions to, simply, the deep tint of the markings as they pass the terminator; and in a few special cases to cloud shadows and other causes associated with clouds. The peculiar feature of the conclusion is that most of the clouds form on the withdrawal of sunlight and not from the convectional currents as with us. This is made not only possible but probable by the fact that the Martian air decreases in density on ascent much more slowly than on the Earth, so that as the moisture dissipates towards the ground at sundown it is less likely to redissolve, and that from the desert character of the planet dust would be likely to exist in considerable quantities in the air, thus assisting in rapidly chilling it as insolation ceased and condensing

the moisture. In particular on November 25, 1894, one immense cloud was observed on the sunrise terminator, having a minimum elevation of 15 miles above the surface. On the following night it had moved nearly 400 miles north and fallen to a minimum elevation of 8 miles, and separated into a number of smaller cloud-masses. On each date it was seen to disappear soon after entering sunlight and before it became projected on the illuminated disk of the planet. This and other observations indicating the absence of clouds by day, their formation at sunset, presumable presence over night and dissipation at sunrise, are of essential importance in explaining the high mean temperature of the planet which must be assumed if we regard the white polar caps as being composed of genuine snow or ice. In 1892 Professor Pickering suggested that such cloud action would account for the high temperature but we believe we have obtained real indications of it.

Throughout the observing season many measures of diameter were made. Upon reducing a large number, Mr. Lowell found that those somewhat separated from opposition gave, after correction, slightly larger values for the equatorial diameter than others exactly at opposition. This he attributes to a twilight effect by which in the gibbous phase the terminator set on by the micrometer and apparent to the eye was actually farther from the planet's center than its theoretical position.

In the opposition of 1896 many of these phenomena were observed but nothing specially novel has yet been deduced.

Of the asteroids, Vesta only has been observed and that very recently. It shows a polar compression of $\frac{1}{10}$, the major diameter being at present apparently within a few degrees of the direction of its orbit. If not exactly in the orbital path, it lies somewhere between that path and a line having 10 degrees greater position angle. Detail has been suspected which would indicate a direct rotation in less than 30 hours. These observations were by the writer assisted by Mr. G. A. Waterbury, Jr. During the months of May and June the diameter of this minor planet was measured and found to be closely 0″.5.

Jupiter itself has not been observed but its satellites have received much attention. To understand the full significance of the results, we must review the early observations of them. In 1892, Professor Pickering at Arequipa discovered their peculiarities of form. He found that the first rotated in $13^h\ 3^m$ and was egg-shaped, having the polar and one equatorial diameter of equal size while the equatorial diameter perpendicular to this one

was some 10 per cent greater. It was by the change in form that he determined the rotation. The other satellites he also found of curious and almost inexplicable forms. He estimated that the second rotated in $41^h\ 24^m$ and that the third and fourth kept the same face towards Jupiter; but in regard to the last he subsequently expressed doubt, and was puzzled in regard to the third satellite. In the summer and autumn of 1894 Professor Pickering made some observations at this Observatory which have not yet received more than a passing inspection; as is the case also with the author's work with the 18-inch in the spring of 1895.

The writer's systematic work began in Mexico in February, 1897. During three weeks of superb seeing and on occasional good nights in the following months of May and June, enough material was obtained to show:—1st, that the first satellite was a spheroid of three unequal axes and that its ellipticity of form had perceptibly increased since 1892 and probably since 1894, that the mean diameter had probably decreased, that the rotation was direct and that its period had certainly been reduced to $12^h\ 25^m.8$; and a map was made exhibiting detail symetrical with respect to its axis, that is, alike on opposite sides; 2d, that detail could frequently be seen on the second satellite, and a direct rotation is probable but no map was made; 3d, that the third satellite presents the same face towards Jupiter, thus having a direct rotation; a map was made of the markings; 4th, that the fourth satellite also presents the same face towards Jupiter; its markings are similar in character to those on the third and in addition appear to be symmetrical with respect to its axis. In the desire to verify this rotation period, no final map has yet been made.

During the present opposition attention has chiefly been given to the first and second. The second may briefly be dismissed by saying that many drawings of detail have been made, which may give the period and map. Observations of the first show that the period is now $12^h\ 24^m.0$ and that in other respects it is practically unchanged from last year. Its elliptical form has been measured by comparison with a scale on every favorable night. Apparently during five hours it retains a ratio of equatorial to polar diameter of closely 119 to 100, usually called by us, simply, ellipticity 119. It then begins to decrease in ellipticity, at first slowly and then quickly until about 112 is reached when its curve of ellipticity turns a sharp angle, rising first abruptly and then slowly until at the end of an hour it has returned to 119. This minimum phase therefore becomes a phenomenon capable of very exact observation. In most cases it has been obtained to within a

minute; yet sometimes it occurs as much as 20 minutes from its predicted time. The weather has prevented very regular observations on this point but there are indications that it depends on the relative positions of the first, second and third satellites.

Saturn has received a small amount of scrutiny, chiefly from Mr. S. L. Boothroyd and Mr. Waterbury, and Titan has been measured for diameter by the writer a number of times, but no systematic work has been done on this beautiful system.

Uranus has been an object of special interest to us during the past spring but announcements in regard to it will be deferred until its next opposition.

The only observations of Neptune have been measures of its satellites by Mr. D. A. Drew.

Such is our four year's work at Flagstaff and in Mexico.

The remainder of my paper, concerning the conditions under which this work has been performed, is less easily disposed of. The explanation that is usually offered for successful effort is that the seeing is better. But such statements in regard to the seeing are very loose because we judge the seeing by the number of things seen. The sentence "We see more at a certain place because the seeing is better," if translated into non-astronomical English, becomes "We see more at a certain place because we see more." We lack technical terms with which to describe the seeing with precision.

For some six years I have been interested in this matter of standard scales of seeing and since 1894 I have been making some attempts to investigate the matter systematically and this year some results have been published giving standard methods of measuring the conditions of the atmosphere, so far as yet developed.* In 1897 I had adopted as the standard, the scale long since devised by Professor W. H. Pickering, which depends directly upon the form of the stellar image, and had made it more precise by limiting it to the form seen in the six-inch aperture. This is as follows:

In a 6-inch aperture,

* Popular Astronomy, June, 1898. In the several articles sent from here to the *Astronomische Nachrichten* of the last year, on this general subject of atmospheric currents, scintillation, etc., nearly every idea was obtained from the writer. The articles were all published during his absence from the the Observatory.

Seeing 0 Means a confused, enlarged mass.
2 means a confused mass not enlarged.
4 means disk well defined, no evidence of rings.
6 means disk well defined, rings broken but traceable.
8 means disk well defined, rings complete but moving.
10 means disk well defined, rings motionless.

With each record is given the vibratory motion of the image, in terms of the angular size of the disk, or in seconds of arc.

If I may be permitted I will digress so far as to give one extra refinement of this scale, which is in prospect. The atmospheric waves have been studied until it can be told which ones are inside the tube, which come from the dome, which come from the local surroundings and which are high up in the air and not to be avoided, and from this study there arises the conclusion that a standard aperture can be found in which the form of the image will roughly indicate the strictly local conditions of the air, and the motions of the image will indicate the general condition of the currents high overhead. The size will probably be between two and four inches. I will add this, that the twinkling of the stars is almost exclusively dependent on the general conditions of the upper air. That has been a valuable fact to remember when judging of the night from the appearance of the stars to the naked eye.

To return to our subject, it may be stated that during last November, December and January, which are among our worst months, the mean seeing at the zenith at Flagstaff, was 7.0 on this standard scale on clear nights and the mean vibratory motion of the image was 1″.0. It was found that profitable work on Jupiter's satellites required seeing 8 with a motion of not over 1″.0 or, rarely a seeing of 7 with reduced motion. Seeing 8 or over was recorded on 70 per cent of the nights included in these means. These measures of our average seeing during three comparatively poor months is a quantitative statement of one general condition under which we work. It will serve as a basis for comparison with any other place in which enough interest is felt to get similar measures.

Another general condition which is of great advantage to us is the fact that in the spring and autumn we are nearly always able to obtain from four to eight weeks in succession in which almost every night is of high quality. This consecutiveness of observation is of far more importance in planetary than in stellar work, because planetary changes are much more rapid. One may state as an axiom that the frequency of observation must

be proportioned to the rapidity of change in the object studied. With double stars it makes no difference whether the given series of measures is made on five successive nights or on five nights separated by irregular intervals. But in planetary work the succession of changes is so rapid that if the observations are scattered at irregular and perhaps long intervals, the results of such observation, even though correct, convey to the mind only a chaotic confusion. It becomes very difficult to coördinate them and derive general laws. The withdrawal of confidence thus produced becomes a strong psychologic effect and explains why people, whose only experience has been of this kind, are so skeptical.

While lack of consecutiveness of observation thus explains rational slowness in accepting our results, the existence of this consecutiveness explains an important part of the certainty with which we speak of our work. Let us suppose an observer suspects or glimpses a new marking. If he sees the same thing on the following night it brings an assurance to his mind that would not occur if bad weather prevented his seeing the same faint glimpse till the third or fourth night after. By that the first impression had faded from his mind and he attributes the whole to imagination or imperfect vision. If in the first case he sees it not only the second night but the third and fourth and many more, his assurance is very strong.

Another example of the value of this consecutiveness of observation will not be amiss. At Flagstaff in fair seeing it is usually easy to become sure that there is detail on the third satellite of Jupiter, but the single view is not good enough to positively identify it. The detail is therefore usually drawn and located as accuratey as possible on several successive nights in order to eliminate the possible misidentification that might occur in single observations.

It seems to be a frequent characteristic of our seeing that we obtain in or near the focus several overlapping images of small planetary objects and it is possible to connect at one instant the detail of one with the outline of another. Therefore one of the chief sources of wrong identification is in erroneous location of detail on this apparent disk. So much does this happen that after getting the most probable configuration it is next to impossible to accurately determine its location. Thus both for form and position of detail a succession of good nights is generally necessary. I have had a similar experience with Uranus. Occasionally the correct position angle of the belts has been recognized at

the first glance, but more often several successive nights must be used so that each may corroborate the other.

Attention is called to a third point in this connection. An observer gets used to the idiosyncrasies of his own locality. He knows better than others how and when to catch the moments of favorable seeing and I believe that each astronomer should be regarded as presumably the highest authority on the capabilities of his own atmosphere in his special line.

My final remarks deal with our special methods of handling the instrument. In the first place we commonly use low magnifying powers. For Mercury and Venus we have used a power of 150, for Mars from 370 to 750, for Vesta 1000, for Jupiter's third and fourth satellites 500, for the first and second 750, for Uranus 370. With a low power there seems to be a great deal more variability in the appearances of planetary detail from moment to moment than with a high power, but the views are more frequent and easier. Mr. Lowell, who used low powers almost exclusively, has remarked to me that he saw the detail on Mars either exceedingly well or not at all. At that time he attributed this to a psychological effect but now it seems to be the characteristic effect of using low power. Again in using a power of 500 on the third satellite of Jupiter I usually see the detail intensely black and sharp or not at all. This has a marked similarity in its impression on ones mind to twinkling and it might be called the twinkling effect. With a power of 750 I occasionally see the detail very much better than in the 500 but such moments are much rarer and unless the night is very good, the use of 750 diameters requires far more constant and wearisome attention.

Although the detail in the lower power is far more easily seen, it is, I believe, not so well seen. For to me it sometimes appears distorted, wide at places, narrow elsewhere, and difficult to locate on the planet and in general less reliable than in the higher power.

A special advantage in using low powers arises from the possibility of decreasing the aperture and thus improving the seeing. This effect is one to be sought in any case and the reason of it is very simple but cannot be discussed at present. I have found that the most effective work can be done when the average apparent size of the markings is approximately the same as small type under ordinary conditions of reading. If the detail is complex it may be necessary to increase the power. Therefore the other custom of ours in handling the telescope is the use of diaphragms as small as possible. This is especially applicable

in the case of Mercury and Venus whose light is much too bright for a 24-inch telescope. A newspaper or book page with so great an illumination would blind us at once. Diaphragming to three or four inches not only reduces the light of these interior planets to a better intensity but vastly improves the seeing. The amount of diaphragming depends on the exact work required. For coarse planetary detail the aperture can be very small. For fine detail more light is required, while for micrometer measuring the aperture must be larger, not to produce more light, but to keep the image steady in the field. In obtaining this steadiness, perfection of definition is lost and one must make the compromise between the two that seems to him best. The diaphragm must never be made so small as to produce obvious diffraction effects.

It seems to me that the habitual use of certain powers, coupled with certain illumination of the object studied, is an important cause of differences in drawings of planetary details among observers. Dr. Barnard, I understand, used powers of 500 and over on Mars and Professor Pickering and I certainly did. Between all three there is a specific similarity in representing detail. Mr. Lowell used low powers, 370 or below, and shows differences from us in representing detail, many of which differences seem to me to be due to the characteristic low power effects.

A criterion for determining the proper powers and aperture for planetary markings is under investigation. It depends upon what seems to me a rational analogy between the act of looking at markings on planets and that of looking at certain markings on white paper, namely printed letters, as one has been accustomed to do from childhood. The criterion may be expressed in this way: Whereas, in any atmosphere except a perfect one, the smaller the aperture, the better the seeing; therefore, for maximum effectiveness, simulate the ordinary conditions of reading to which the eye and brain have become accustomed, by the use of such powers as make the detail about the apparent size of small type, and such apertures as make the apparent illumination of the planetary disk about that of printed matter under ordinary reading conditions.

This plan is not wholly new. Astronomers have long been accustomed to use lower powers when the seeing becomes worse. Now it appears that the really important thing is to reduce the aperture as well.

While we are thus guided in adapting ourselves to changing conditions, this criterion also saves experiment by supplying us at once with a constant relation between the power and aperture

and size of detail. So that in search for detail of a given size we can assign at once the proper power and aperture, and if we see that detail easily and wish to try for other markings of, perhaps, half the average size, we have only to double the power and aperture; as will appear from the following investigation.

I find by measurement that the average size of newspaper type which I have been reading during the past three months is about 10′ of arc or about one-third the apparent size of the Moon; and I have found by trial that a good reading illumination is $\frac{1}{1000}$ of full sunlight on the printed matter. Therefore putting:

a = aperture of telescope in inches
e = ⅛ inch = pupil of eye under good reading illumination.
p = power
d = distance of planet from Sun in terms of Earth's distance
s = 600″ = apparent size of small type
z = largest dimensions of markings examined in seconds of arc
l = albedo of planet
m = .7 = approximate albedo of reading matter and
$i = \frac{1}{1000}$ = desirable illumination of reading matter in terms of the illumiation of such matter held in full sunlight at distance unity from Sun.

We have, neglecting the absorption of the lenses,

(1) $$p = \frac{s}{z}$$

(2) $$i = \frac{1}{d^2} \cdot \frac{l}{m} \cdot \left(\frac{a/e}{p}\right)^2$$

in which $\frac{a}{e}$ gives the power at which the object theoretically has the same brilliancy as to the naked eye, because the emergent pencil exactly fills the pupil. The square of this power divided by the square of the power employed therefore is directly proportional to the apparent brilliancy of the object.

Transposing and taking the square root, we have:

$$a = dep\sqrt{\frac{im}{l}} \text{ or, putting } \frac{s}{z} \text{ for } p$$

(3) $$a = es\sqrt{im} \cdot \frac{d}{z\sqrt{l}}$$

(4) $$a = \frac{2d}{z\sqrt{l}} \quad \text{very closely.}$$

In accordance with (1) and (4) the following table has been worked out, in which l and d are taken from Young's Astronomy

and Barnard's measurements of the asteroids, and z is assigned as carefully as possible from experience. It is undoubtedly also some function of the actual contrast between the markings and their surroundings.

Planet.	d	1	z	Power.	Aperture.
			"		in.
Mercury	⅓	.13	8	75	¼
Venus	⅔	.50	12	50	1/7
Mars	1½	.26	1.0	600	6
Vesta	3	.7	.5	1200	14
Pallas and Ceres	3	.2	.6	1000	22
Jupiter's Sat.'s	5	.6	1.0	600	13
Titan	9	.5	5	1200	51
Uranus	19	.64	4.0	150	12
Neptune	30	46	2.6	230	34

I cannot go more into details at present but while none of these results are with certainty in precise accord with experience, yet nearly all that have been tried are good approximations. Of course some of these smaller apertures are inadmissable in any case from diffraction effects.

So far as I know this is the first attempt to establish a principle upon which to determine the proper powers and apertures for planetary markings.

August 17, 1898.

ATLAS OF VARIABLE STARS.

J. G. HAGEN, S. J.

The preparation of an Atlas of Variable Stars at the Georgetown College Observatory has already been brought to the notice of astronomers. The first series of charts is nearly printed and will be issued in a few weeks. It comprises those variables, whose light at minimum falls below the 10th magnitude, and whose declination is between 0° and — 25°.

Of the utility of this Atlas little need be said. It will prove indispensible as well to the professional astronomer who wishes to observe Variable Stars in a systematic way, as to the amateur, who can find no readier means of really adding to the sum of scientific knowledge than by variable star observations. The division of the Atlas into five series will furnish the observer fully with whatever program may be adapted to his instrumental means and his geographical position. The charts will enable him to identify the variable without loss of time, and the catalogues will give him the positions and magnitudes of the comparison stars.

The brightness of the latter is expressed in steps and in magnitudes, with references to the Bonn Durchmusterung and other catalogues. Specimens of charts were published last October in the *Nachrichten* and in the *Astrophysical Journal*. The names of Wolz and Henry, who also engraved and printed Schönfeld's DM., will be a guaranty for the technical features of the Atlas.

The price has been fixed by the publisher, Mr. F. L. Dames, of Berlin, as follows: To subscribers for all the five series together the rate will be 1 Mark per chart, but for each series separately 1.20 Mark per chart. In both cases the catalogue is included in this price. The present series comprises 44 charts. The author wishes to say, that so far as concerns himself his only reward will be the pleasure of having promoted this branch of astronomy. Nor does the publisher consider the work a source of gain, as will be seen from the following statement. The cost of engraving and printing the whole Atlas will be about $7,000, one-fourth of which is guaranteed by the well known benefactress, Miss Catherine W. Bruce. Estimating the selling price in round numbers at $50, it is clear that one hundred subscribers to the entire Atlas will not pay the engraver and printer. The publisher therefore makes a strong appeal for further aid, in order to secure the completion of the Atlas. For this assistance he looks especially to the astronomers of this country, because at present this field of astronomy is more cultivated here than elsewhere.

Our American committee on the northern Durchmusterung was so successful that it secured more thau one half the required number of subscribers (see *Astroph. J.* VII, p. 295, VIII, p. 197). Encouraged by this fact, the chairman, Professor Edward C. Pickering, has kindly suggested the issue of this circular, with the promise to give it a wide circulation throughout the country. Orders may be sent either directly to Mr. Felix L. Dames (Landgrafen Strasse 12, Berlin W. 62, Germany), or for the convenience of subscribers, through the Harvard College Observatory or the undersigned.

GEORGETOWN COLLEGE OBSERVATORY,
Washington, D. C., December 8, 1898.

THE ETHER.

FREDERICK HUTTON GETMAN.

There is no one hypothesis to which modern physics owes more than to that of the existence of the ether. Take away the

ether from the physicist and his failure to explain the phenomena of light, heat, and electricity and magnetism would at once follow.

It may be called the great corner stone of modern physical science. Ethers have been postulated by various philosophers from the year 350 B. C., when Aristotle described his pellucid to the time of Huyghens in 1680. With the exception of the ether assumed by Huyghens all have proven incapable of offering satisfactory explanation of the phenomena presented. Some philosophers assumed an ether in which the planets could "float." Others claimed that in order for the Sun to rule his universe there must be some connecting link or medium between the Sun and the members of the solar system through which the force of gravitation could act.

James Clerk Maxwell says of these various ethers:—"Ethers were invented for the planets to swim in, to constitute electric atmospheres and magnetic effluvia, to convey sensations from one part of our body to another, till all space was filled several times over with ethers."

Newton tells us in one of his writings that he had invented an ether in which his "light corpuscles" could be projected into space by the source of light. He also devised an ether to account for gravitation but he did not publish his theory because he says, "I was not able from experiment and observation to give a satisfactory account of this medium, and the manner of its operation in producing the chief phenomena of nature."

It was not, however, until the time of Huyghens, in 1680, that the ether hypothesis of to-day was formulated. The experiments of Dr. Thos. Young in England, and the work of Fresnel in France, made it necessary to assume some such medium as the ether that light might logically be conceived as a wave-like disturbance. The whole scientific world was at this time under the influence of the master-mind of Sir Isaac Newton and his corpuscular theory of light with its ether and all of the attendant encumbrances was held as the correct theory. For this reason Huyghens' wave theory and his ether were slow to find scientific recognition. However, the readiness with which refraction, interference and diffraction were explained made it a theory too firm to be overthrown, and gradually it was accepted by the scientific men of the time. Each new discovery has strengthened its claims upon the minds of men of science.

The phenomena of light, radiant heat and electro-magnetism are all explained by the aid of this one medium. There is also

strong probability that gravitation takes the ether for its vehicle. The tendency of modern physics is to make the ether the great reservoir of all energy. Probably in the ether all energy is kinetic. If this is the case, potential energy will become a relic. In order that the ether may convey undulations with a finite velocity and also carry energy it has been assigned two fundamental properties—elasticity and density. Now light and radiant heat are known to be transverse vibrations in the ether, and in order that this medium may transmit such vibrations it has been supposed to possess something of the nature of a highly elastic solid, for liquids and gases cannot transmit transverse vibrations. The ether is also supposed to be incompressible. The vibrations of solid bodies travel much too slowly to admit of our assuming them capable of causing the propagation of light, hence the ether is supposed to interpenetrate all matter.

The impossibility of this hypothesis is to be overlooked when we reflect that our senses tell us nothing of this medium. It is wholly by intellectual reasoning that we can prove its existence. We know that the magnet attracts iron filings even though a glass plate be interposed, and while our senses tell us nothing directly about this, yet we must not fail to conclude that there is some medium by means of which the iron receives the energy of the magnet.

Dr. Thos. Young imagined the ether to pass directly through solids with as much ease as air passes through a grove of trees.

Sir William Thomson, who probably knows more about the ether to-day than any other scientist, is a firm believer in the elastic solid theory. To illustrate how the ether can behave as a rigid elastic-solid permitting the planets to move through it with ease, he performed the following simple yet forceful experiment. He took a large slab of shoemaker's wax, about two inches in thickness, and fitted it in a glass jar 10 or 12 inches in diameter. Then he filled the jar with water and laid the cake of wax in it with a number of corks underneath and two or three bullets on top. He then set the jar away in a place where it would not be disturbed and left it for six months. At the end of this time the bullets had all disappeared and the corks were fully half way through the wax. Before a year had passed the bullets lay on the bottom of the jar and the corks were floating on the water. The conclusion reached was that if the wax represented the ether and the bullets and corks represented the planets then very small forces suffice to prove change of shape. The wax, like the ether, is elastic, and may be moulded into a tuning fork which will vi-

brate when struck. It is also brittle and yet something like a fluid. Certainly, no one experiment could illustrate better the the operation of Huyghen's ether.

That gross matter has some effect upon the ether we are quite certain, but in just what way it effects this curious medium science has not yet told us. In an experiment by Fizeau on the velocity of light in a stream of water he found that the velocity of propagation was greater in the direction of the current than in the opposite direction and from this he argues that the ether contained by the water is carried along with it. That is, we infer the ether to have a relative motion but this is not sufficient evidence to say that gross matter does effect the ether. All of this reasoning about this medium, the ether, seems very vague and yet when we pause to think how little we know of the constitution of common substances, we must confess that our knowledge of the ether is not so slight, relatively speaking. Sir William Thomson says—"It seems to me we must know a great deal more about the ether than we do. But instead of beginning with saying that we know nothing about it, I say that we know more about it than we do about air or water, glass or iron—it is far simpler, there is far less to know."—*Popular Science, January, 1899.*

SPECTROSCOPIC NOTES.

At the anniversary meeting of the Royal Society Nov. 30 the Copley medal was awarded to Sir William Huggins for his great achievements in the application of spectrum analysis to the heavenly bodies. The president in summarizing the work of the medalist mentions that his first results were obtained in 1864, when, working in conjunction with Professor Miller, he measured visually a large number of lines in the spectra of Betelgeux and Aldebaran, and compared them with lines in the spectra of terrestrial elements. On Aug. 29, 1864, he made his epoch-making discovery of the bright line spectra characteristic of certain nebulæ, establishing the fact that these nebulæ are gaseous; he also identified one of the nebular lines with a hydrogen line. In 1868 he applied Doppler's principle to the measurement of stellar movements in the line of sight, a most productive field subsequently under the cultivation of other astronomers, as witness spectroscopic doubles, the movements of Algol, and the confirmation of the mathematical theory of Saturn's ring. In 1868 he studied the spectrum of Winnecke's comet, and found carbon a constituent of comets. Following Draper he obtained in 1876 a photograph of the spectrum of Vega, and at that time discovered the remarkable series of hydrogen lines characteristic of the "white stars," such as Sirius and Vega. He succeeded in 1881 in photographing the spectrum of Tebbutt's comet; and in photographing the spectrum of the Orion nebula in 1882, and the same (with Lady Huggins) better in 1888 and 1889. In 1889 they studied photographically the spectrum of Uranus. Very recently they have investigated the ultra-violet lines of calcium in their bearing on the solar spectrum.

In the *Astrophysical Journal* for November and December Mr. Very has a long and readable article on the temperature of the Moon. The first section deals with the radiating power of various substances resembling more or less the assumed lunar surface; the latter half has to do more directly with the character of the lunar radiation. How much the subject is of necessity speculative may be judged from the reasoning that, while on the arid Moon extensive salt deposits are possible, the surface is probably covered by a layer of cosmic dust; further, while it is increasingly probable that cosmic dust is metallic, the particles are probably coated with oxide and so for radiating purposes probably similar to sooted copper. The familiar statement that the Moon's temperature is shown to be low by the absorption of much of its energy by glass, he contests on the ground that the observation is vitiated by atmospheric absorption. His observations lead him to contend for a temperature at noon of the long lunar day of near 100° C (212° F), approached only by the most terrible of the Earth's deserts. The measures adduced do indeed seem to support a hot lunar noon; but it will probably require abundant evidence to overthrow the idea of a cold lunar noon, which the average layman deduces for himself from the fact that the top of Cotopaxi is white.

In a work of a very popular character by Dr. Meyer (Das Weltgebäude, von Dr. M. Wilhelm Meyer, Leipzig und Wien 1898) it is gratifying to notice, as indicating increasing popular attention to the important results of spectroscopic observation, an account of so recent a thing as Professor Campbell's contention against the reality of the spectroscopic evidence for water vapor in the atmosphere of Mars; and a mention, in the main correct, of Professor Keeler's work—too little known—on the motion of nebulæ in the line of sight.

Professor Campbell (*Astrophysical Journal* Dec.) finds for o Leonis a variable velocity in the line of sight, ranging from 67 kilometers (42 miles) per second of recession to 30 km. (19 miles) per sec. of approach, with a period of 14½ days; for this star there is some evidence that the spectrum consists of two superposed spectra. And from twelve plates he finds for χ Draconis a variable velocity ranging from 46 km. (29 mi.) per second of recession to 11 km. (7 mi.) per sec. of recession; the observations indicating a period of five to six months.

Sir George Baden-Powell died Nov. 20, 1898. While he was not an astronomer, it will be remembered that he conveyed on his yacht *Otaria* the expedition to Nova Zembla to observe the total eclipse of the Sun Aug. 9, 1896, when Mr. Shackleton secured his memorable photograph of the "flash" spectrum at the end of totality. The spirited and determined way in which he undertook to put the party in the path of totality at that remote station may be appreciated from some remarks in his description of the expedition before the Royal Astronomical Society Dec. 11, 1896, (*Observatory*, 20 : 44) :—

"In the first place, it was necessary, in my opinion, to get some qualified astronomers with their instruments to Novaya Zemlya. I happened to wish to go there for other purposes connected with meeting my old friend Dr. Nansen. Hearing that I could be of some service to science I was glad to devote all the abilities I possessed, and my ship, to taking these astronomers there. We had some difficulty in getting there in time, but, as has happened before in certain things we have undertaken in that good ship, we got there well in time."

And, once arrived at this trying Arctic observing station, the heartiness

with which he entered into the observations may be judged from some later sentences on the same occasion:—

"They entrusted to my charge the coronagraph, and all the members of my crew not only took their part with extraordinary willingness, but also showed great delight in what they considered an interesting observation, considering that they had their reward in being allotted positions around the instruments under the command of these distinguished astronomers. Right at the last moment, however, the siderostat would not work. It had been set up and thoroughly adjusted, but at the last moment, when the Moon had got a long way over the Sun, it would not work; and looking through the coronagraph telescope I saw the image pass steadily but surely across that bit of ground glass which we all watched so anxiously, and nothing that the devoted energy of Mr. Shackleton could do would make it work properly. This happened almost up to the point of totality, but, with the dash of genius, Mr. Shackleton certainly went for that siderostat with what we uninstructed persons would call rashness, and dashed back into the hut saying 'that will do,' and it did do. I saw the image in the center of my ground-glass, which I had then to take out and begin the series of photographs I had been instructed to take at various intervals during totality; and I think one of the happiest moments of my life was when somewhat dazed, because immediately after totality the burst of sunlight was so great, I had sufficient senses left to slip in the ground-glass to see where the Sun had got to, and saw our old friend right in the center of the field."

Commenting on the inadequacy of the appropriations of public money for eclipse expeditions he added:—

"But I do say for myself—and I have a special command to do so for my wife—that if ever a yacht is wanted to take willing people to see another eclipse they will know where to find it if we are free then."

Surely, this was an expedition that deserved to succeed so brilliantly in the midst of general failure due to bad weather.

An appendix to the *Monthly Notices of the Royal Astronomical Society*, Vol. 58, contains the 'Preliminary Reports on the British Goverment Expeditions' to observe the total eclipse of Jan. 22, 1898, in India. Among Professor Copeland's equipment at Ghoglee were a small prismatic camera arranged for the ultra-violet spectrum, an integrating spectroscope, and a horizontal telescope of 4 inches aperture and 38 ft. focal length with fixed mirror and plate-holder moved by clockwork; a direct vision prism could instantly be placed in front of the object glass of this telescope, making it a long prismatic camera. Three spectrum photographs were taken with the 38 ft., the last of the three just after totality, showing numerous bright lines. Sir Norman Lockyer, at Viziadrug, was assisted by Mr. A. Fowler and Dr. W. J. S. Lockyer, and as usual by an imposing array of amateur observers. His spectroscopic equipment included two large prismatic cameras and an integrating spectroscope. Many exposures were taken with the prismatic cameras, and at the end of this report is given a table containing the heights deduced for the vapors giving various lines. The examination of the plates is stated to be incomplete. At Pulgaon Captain Hills and Mr. Newall observed successfully with a grating before the object glass of a small telescope, giving a distorted ring due to the 'Coronium' line; and with two prismatic cameras, one arranged for the ultra-violet, the other securing successful photographs of the spectrum of the Sun's limb.

Professor George E. Hale communicated to the Second Conference of Astronomers and Astrophysicists at the Harvard Observatory last summer an account of an investigation of the spectra of stars of Secchi's fourth type, of which an abstract is given in the *Astrophysical Review* for November. He defends his belief, as against Dunér's opinion, that certain bright places are really bright lines, and not bright by contrast only. Detecting a similarity to the spectra of the Wolf-Rayet stars, he requested Mr. J. A. Parkhurst to examine the distribution in the sky of the fourth type stars, with the result that he found they exhibit a greater tendency to cluster in the Milky Way than any other class of stars except the Wolf-Rayet stars. The work is being continued with the 40-inch telescope at the Yerkes Observatory.

VARIABLE STARS

J. A. PARKHURST

Maxima and Minima of Long Period Variables.

1899.

MAXIMA.

Jan.		Mag.	Day.
234	U Cassiopeæ	8.0	14
267	V Andromedæ	8.4	3
494	R Sculptoris	5.7	29
1222	R Persei	7.7	26
1623	T Camelopard.	7.0	26
2583	l_2 Puppis	3.5	18
2676	U Monocerotis	5.9	24
4056	RS Centauri	9.2	29
4573	RU Virginis	8	6
5095	R Centauri	6.0	29
5338	U Bootis	9.1	22
6062	RR Scorpii	6.8	21
6207	Z Ophiuchi	7.5	23
7045	R Cygni	5.9	30
7106	S Vulpeculae	8.3	8.4
7257	R Sagittæ	8.5	20
7260	Z Aquilæ	8.8	22
7571	V Capricorni	9	24
8230	S Aquarii	7.7	5
Feb.			
893	U Ceti	6.8	24
1805	V Orionis	8.4	18
3244	S Pyxidis	8.3	1
3495	*l* Carinæ	3.7	1
5174	RS Virginis	8.2	8
5249	V Libræ	9.3	24
5321	S Lupi	9.7	20
5583	X Libræ	9.5	23
5704	RR Libræ	8.4	10
5758	X Herculis	5.9	12
5903	Y Scorpii	10	3
5931	S Ophiuchi	8.3	6
6608	RV Sagittarii	8.2	5
6794	R Lyræ	4.0	3
6943	T Sagittæ	8.3	6
7139	RR Sagittarii	7.5	20
7220	S Cygni	8.8	2
7560	R Vulpeculæ	7.5	14
8600	R Cassiopeæ	4.8	26

MINIMA.

Jan.		Mag.	Day.
678	U Persei	11.6	28
1717	V Tauri	< 13.5	9
2266	V Monocerotis	10.7	11
2445	W Monocerotis	< 10	31
2676	U Monocerotis	8.0	6
3425	X Hydræ	11.8	30
3495	*l* Carinæ	5.2	19
4826	R Hydræ	9.7	30
4896	T Centauri	9.2	25
6794	R Lyræ	4.7	11
7242	S Aquilæ	11.8	2
7252	W Capricorni	< 14.7	5
7257	R Sagittæ	10.4	4
Feb.			
103	T Andromedæ	13	20
146	T Sculptoris	10.0	1
782	R Arietis	13.0	9
2080	R Columbæ	11.4	< 3
2528	R Geminorum	< 13.5	4
2676	U Monocerotis	8.0	21
2684	S Canis Minoris	12.7	1
3493	R Leonis	10.0	2
3495	*l* Carinæ	5.2	23
3994	S Leonis	< 13	20
4492	Y Virginis	13	17
4557	S Ursæ Majoris	11.5	28
4596	U Virginis	12.8	10
4940	W Hydræ	8.0	23
5194	V Bootis	10.5	12
5237	R Bootis	12.2	24
5795	W Scorpii	< 14.7	16
5950	W Herculis	14	12
5955	R Draconis	13	23
6512	T Herculis	12.7	11
6794	R Lyræ	4.7	27
7106	S Vulpeculæ	10.0	14
7404	R Microscopii	12.0	10
7428	V Cygni	13.5	26
7431	S Delphini	12.0	27
7754	W Cygni	6.7	10

MAXIMA.

March.		Mag.	Day.
434	S Piscium	8.2	17
845	R Ceti	7.5	26
1581	S Tauri	9.3	10
2676	U Monocerotis	5.9	11
2735	U Canis Minoris	8.5	16
3060	U Cancri	8.4	23
3264	W Cancri	9.6	28
3495	*l* Carinae	3.7	9
3637	S Carinae	6.0	22
4816	V Virginis	8.0	21
4896	T Centauri	5.9	8
5430	T Librae	9.2	8
5494	S Librae	7.6	7
5504	S Coronae	6.1	4
5511	RS Librae	8.2	12
5776	X Scorpii	10	8
5887	V Ophiuchi	7.0	31
6794	R Lyrae	4.0	21
7085	RT Cygni	7.0	5
7106	S Vulpeculae	8.4	12
7242	S Aquilae	8.4	15
7257	R Sagittae	8.5	31
7444	T Delphini	8.2	5
7448	W Aquarii	8.0	21
7455	U Capricorni	10.2	29

(MAXIMA, Con't).

March.		Mag.	Day.
7468	T Aquarii	6.7	8
7577	X Capricorni	9.5	28
7733	Y Capricorni	10	20
7792	SS Cygni	8.5	12
7994	R Piscis Austr.	8.5	8
8068	S Lacertae	7.6	12

MINIMA.

March.		Mag.	Day.
432	S Cassiopea	< 13.5	25
466	U Piscium	14.5	7
2583	L_2 Puppis	6.3	30
3418	R Carinae	9.3	2
3477	R Leonis min.	13	1
3495	*l* Carinae	5 2	31
4511	T Ursae Maj.	13.0	16
4521	R Virginis	11.0	9
5465	R Triang. austr.	8 0	14
5758	X Herculis	7.2	16
7192	Z Cygni	12	8
7257	R Sagittae	10.4	15
7260	Z Aquilae	11	21
7779	S Cephei	12.3	22
7783	RU Cygni	9.2	22

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

	d	h
Mar.	4	6
	6	18
	9	6
	11	18
	14	6
	16	18
	21	17
	26	17
	31	16

ALGOL.

	d	h
Mar.	3	12
	6	9
	9	6
	20	17
	23	14
	26	11
	29	8

λ TAURI.

	d	h
Mar.	1	15
	5	14
	9	13
	13	12
	17	10
	21	9
	25	8
	29	7

R CANIS MAJ.

Every 8th min.

P = 1^d 3^h.3

	d	h
Mar.	7	23
	17	1
	26	3

S CANCRI.

	d	h
Mar.	10	20
	20	7

S CANCRI Con.

	d	h
Mar.	29	19

δ LIBRÆ.

	d	h
Mar.	1	22
	6	14
	8	22
	13	14
	15	22
	20	13
	22	21
	27	13
	29	21

U CORONÆ.

	d	h
Mar.	3	23
	7	10
	10	21
	14	8
	17	19
	24	16
	31	14

U OPHIUCHI.

Every 10th min.

P = 20^h.13

	d	h
Mar.	6	17
	15	2
	23	11
	31	20

RS SAGITTARII.

	d	h
Mar.	4	17
	9	13
	11	23
	16	19
	21	15
	28	21

W DELPHINI.

	d	h
Mar.	8	22
	13	17

The above ephemeris of Long Period Variables is in form similar to that of last year. The dates are taken from the ephemeris by M. Loewy in the *Companion to the Observatory* for 1899. The lettering of some of the stars in that list is changed to conform to Dr. Chandler's notation. The usual lettering RS and RT, for instance, is given S^2 and T^2 in M. Loewy's ephemeris, and SS is given S^3. The ephemeris of the Algol Type Stars is, as before, computed from the elements in the Third Catalogue and supplements.

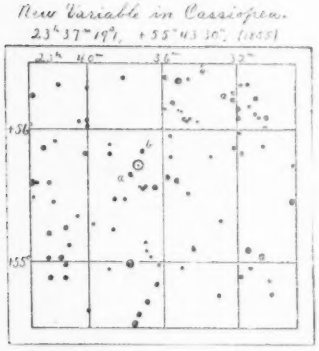
CERASKI'S VARIABLE IN AURIGA, charted on page 43 of the January number, has remained at about 9th magnitude since Dec. 10. Its position is

R. A. $5^h\ 17^m\ 6^s$, Decl. $+ 36°\ 46'.6$, (1855)

Through an engraver's mistake the charts were reduced to ¼ the size of the drawing, instead of ½, as usual, so that the heading "Scale of the DM" should read "Scale ½ that of the DM."

NEW VARIABLE IN CASSIOPEA. This was discovered by Rev. Thos. D. Anderson and announced in No. 3533 of the *Nachrichten*. He found it in 1897, though not in the DM, only $0^m.2$ fainter than $+ 55°{,}3007$, (marked *b* on the accompanying chart, $9^m.0$). Since then it was invisible, though the $10^m.3$ star, marked *c* on the chart, was easily seen. On Dec. 5, 1898, he found the variable midway in brightness between *b* and *c*. On receiving the notice in the *Nachrichten*, I looked up the field on a photograph taken with a 2-inch portrait lens, 1898, Nov. 11, and found the variable decidedly fainter at that date than the star *c*, though this might have been caused by the red color so common to variables. On 1899, Jan. 4, the variable was nearly one magnitude fainter than *c*, visually. The effect of color is strikingly illustrated in this same field by the star *a*, which is DM + 55° 3011, visual magnitude 8.3 This is No. 2121 in Krüger's *Catalogue of Colored Stars*, and was found to be of spectral type III′, color orange-red, by Espin. Photographically this is $8^m.3$ star is fainter than the star *c*, $9^m.0$. The posltion of the variable, as measured from the stars *a* and *b*, which are in the *Helsingfors-Gotha Astronomische Gesellschaft Catalogue*, is

R. A. $23^h\ 37^m\ 19.1^s$, Decl. $+ 55°\ 43'\ 30''$, (1855)
$39\ \ 29.0$ $\quad\quad 58\ \ 28\ \ ,$ (1900)



COMPARISON STARS FOR ANDERSON'S NEW VARIABLE IN CASSIOPEA.

	Co-or. from the Var. R. A.		Decl.	Mag.		Co-or. from the Var. R. A.		Decl.	Mag.
	′	ˢ	′			′	ˢ	′	
h	− 2.9	− 20.7	+ 3.2	10	*e*	0	0	+ 0.8	12
b	− 1.9	− 13.6	+ 6.4	9.0	*c*	+ 1.7	− 12.1	+ 3.1	10.3
t	− 1.6	− 11.6	− 3.9	12	*d*	+ 2.3	− 16.2	+ 5.2	10.5
g	− 1.6	− 11.6	− 2.1	11.5	*a*	+ 3.9	− 27.6	− 4.4	8.3

With a power of 200 the variable seems to have a 12^m companion in the esti-

mated position angle 200°, distance 3″ or 4″, but a larger aperture is needed to make the duplicity certain.*

SS CYGNI. After a period of normal brightness lasting 46 days, SS began to rise to maximum 1899, Jan. 6. As the maximum will be completed too late for this number, the full report is reserved for the March number, when a resumé of the past year's results will be given.

A NEW STAR OF TYPE IV. In Wolsingham Observatory Circular No. 48, Rev. T. E. Espin reports the discovery of a red star of Type IV, $8^m.4$, but not in the DM, at R. A. $4^h\ 19^m\ 49^s$, Decl. $+\ 39°\ 32'$, (1855). The galactic latitude of this star is 6½°, conforming to the remarkable tendency of IV Type stars to congregate in the Milky Way. The number of IV Type stars in a zone 10° wide, extending 5° each side of the galactic equator, in the northern hemisphere, is 27 times as great as the number in an equal area of sky around the northern galactic pole.

This new IV Type star is at least ¾^m brighter than a neighboring Durchmusterung star 1 min. following and 5′ or 6′ south, so that it is quite probable that it is a variable.

BETELGEUZE. Mr. R. T. A. Innes has the following note in a late *Nachrichten*: "I have observed Betelgeuze on several occasions recently as only slightly brighter than Aldebaran. Last season up to their disappearance in twilight Betelgeuze was twice as bright as Aldebaran which is its ordinary state. One of the irregular minima of Betelgeuze may be approaching."

PLANET NOTES FOR FEBRUARY.

H. C. WILSON

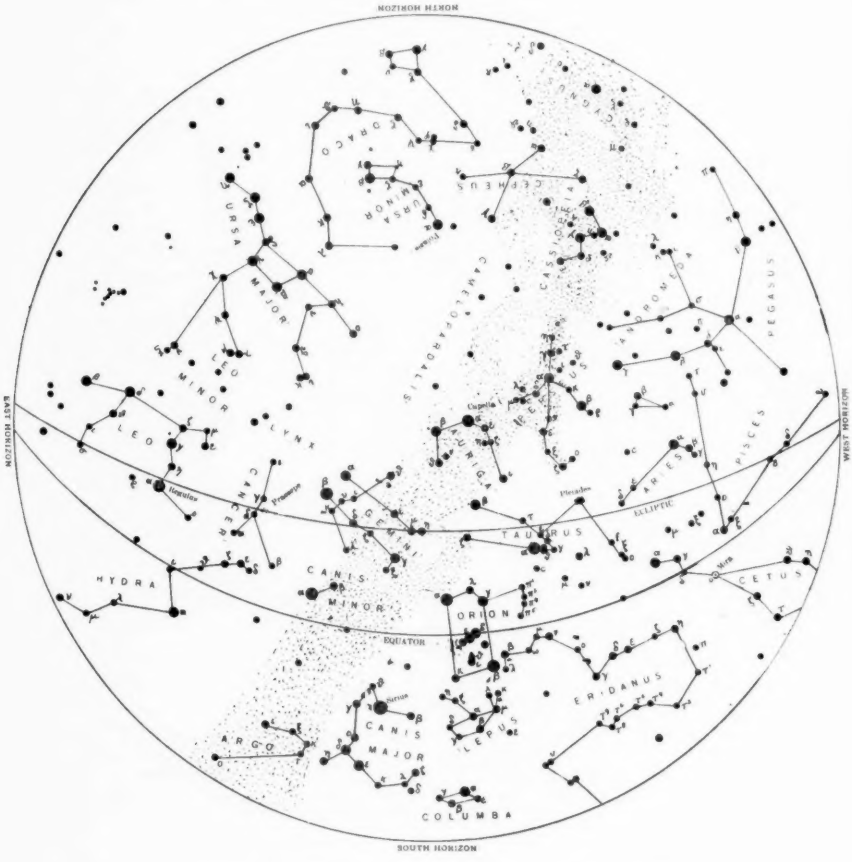
Mercury will be invisible to the naked eye, coming to superior conjunction on Feb. 27.

Venus has been so very brilliant in the morning during the past month that she cannot fail to have attracted the attention of those who are awake before daylight. Seen toward the southeast in the early morning, when one's eyes after long sleep are most sensitive, her brilliancy is dazzling, far surpassing that of any other object in the sky, save the Moon. The maximum of brightness was passed early in January, and she has now begun to wane but for several months will continue to be a striking object in the southeastern sky. Venus will be at greatest elongation west from the Sun, 46° 52′, on Feb. 10. The waning Moon will be in conjunction with Venus, 4° 18′ south of the latter, on Feb. 6 at 7^h P. M. Central Standard time.

Mars is now the planet for evening observation, seen toward the east and well up toward the zenith at 9 o'clock, in the constellation Gemini, south of the stars Castor and Pollux. Mars is much brighter than these two stars and its orange red color renders the planet a conspicuous object. With a good telescope one may see the more prominent markings upon the surface of the planet, and those more favored with clearness and steadiness of atmosphere may also be able to see some of the enigmatic "canals." Mars is now turning the apparent

* NOTE. Since the above was written Professor Geo. C. Comstock has kindly examined the star with the 15½-inch Washburn refractor and finds it to be double, estimating the position angle to be 30°, or perhaps 210°, and distance 3″.

loop in its path in Gemini, will reach the stationary point Feb. 27, and will after that move eastward. The Moon passes through Gemini Feb. 21, being in conjunction with Mars at 11^h A. M.



THE CONSTELLATIONS AT 9 P. M., FEBRUARY 1, 1899.

Jupiter may be observed in the morning, seen toward the south at 6 o'clock. The planet is moving westward now between the constellations Libra and Virgo but will reach the stationary point and turn eastward on Feb. 24. It may be easily distinguished from the neighboring stars by its great brightness. Jupiter and the Moon will be in conjunction on the morning of Feb. 3.

Saturn and *Uranus*, being between Jupiter and Venus, in the constellation Scorpio, may be seen at the same time. All these planets are seen at a low alti-

tude at best in our latitude and are not favorably situated for good observations of their surface markings. For observers in the southern hemisphere the reverse is true.

Neptune is in convenient position for observing, being near the meridian from 8 to 9 o'clock in the evening at a high altitude. This planet is invisible to the eye, but may be found with a telescope about 2° west from the star ζ (Zeta) in the tip of the southern horn of Taurus.

The Moon.

	Phases.	Rises. (Central Standard time at Northfield; Local Time 13m less.)		Sets.	
		h	m	h	m
Feb. 3	Last Quarter	1	0 A. M.	10	33 A. M.
10	New Moon	7	12 A. M.	6	24 P. M.
17	First Quarter	10	39 A. M.	2	42 A. M.
25	Full Moon	6	26 P. M.	6	58 "

Occultations Visible at Washington.

Date 1899.	Star's Name.	Magnitude.	IMMERSION. Washington M. T.		Angle from N pt.	EMERSION. Washington M. T.		Angle from N pt.	Duration.	
			h	m	°	h	m	°	h	m
Feb. 1	75 Virginis	6.0	10	20	109	12	21	306	1	1
4	22 Scorpii	5.5	16	4	80	17	11	307	1	7
16	B. A. C. 1055	6.8	4	19	81	5	46	241	1	27
19	2 Geminorum	7.2	4	41	143	5	29	214	0	48
19	12 Geminorum	7.5	13	17	87	14	15	304	0	58
21	B. A. C. 2658	7.2	14	6	87	15	3	321	0	57
25	p^2 Leonis	5.4	14	19	166	15	20	265	1	1
26	B. A. C. 4006	6.1	15	31	123	16	48	300	1	17
27	q Virginis	5.7	12	15	57	12	46	13	0	31

COMET NOTES.

Elements of Comet *j* 1898 (Chase).—In the *Astronomische Nachrichten*, No. 3531, are the following new elements of this comet, calculated by F. Möller from observations Nov. 14, Nov. 23, Nov. 25 and Dec. 5:

$$\begin{aligned} T &= 1898 \text{ Sept. } 19.64919 \text{ Berlin M. T.} \\ \omega &= 4^\circ\ 23'\ 9''.2 \\ \nu &= 95\ 47\ 0\ .2 \\ i &= 22\ 28\ 25.2 \\ \log q &= 0.357918 \end{aligned}$$

The middle places are both represented within 6″ so that there is little evidence of ellipticity. From these elements Dr. H. Kreutz has computed an ephemeris, of which the portion for February is as follows:

EPHEMERIS OF COMET *j* 1898.

Berlin Mid.	App. R.A. h m s	App. Decl. ° ′	log r	log Δ	Br.
Feb. 2	11 8 23	+34 40.5			
4	7 48	35 1.0	0.4398	0.2707	1.02
6	7 8	35 20.8			
8	6 23	35 39.9	0.4437	0.2739	0.99
10	5 35	35 58.0			

Berlin Mid.	App. R.A. h m s	App. Decl. ° ′	log *r*	log Δ	Br.
12	4 42	36 15.2	0.4475	0.2780	0.96
14	3 46	36 31.5			
16	2 47	36 46.9	0.4514	0.2829	0.92
18	1 45	37 1.6			
20	11 0 42	37 15.4	0.4554	0.2885	0.88
22	10 59 38	37 27.1			
24	58 34	37 37.4	0.4593	0.2952	0.84
26	57 29	37 47.3			
28	10 56 24	+ 37 55.8	0.4633	0.3024	0.80

GENERAL NOTES.

Color Phenomena Attending the Earth's Shadow at Sunset.—The sunset phenomena so interestingly described by Dr. Swift in the December number of POPULAR ASTRONOMY are always visible at Mt. Hamilton during the summer months, and can probably be seen at most places where the air is reasonably clear, the view unobstructed, and the western horizon free from clouds at sunset.

Dr. Swift is, I think, wrong in attributing these appearances to refraction of sunlight by the earth's atmosphere. Atmospheric dispersion is a matter of seconds, rather than of degrees. The explanation which I have always regarded as satisfactory, and which, I have little doubt, is substantially correct, is as follows.

The deep blue of the earth's shadow, as it rises above the horizon, is not a spectral blue; it is the blue of a smoke-cloud seen on a dark background by reflected light—the blue of distant mountains, and was fully explained by Tyndall. The boundary of the shadow is not sharp, partly because the Sun is not a point, and partly because the shadow is not projected on a plane, but on space filled with particles of haze. It is therefore a surface, and the eye is not in this surface, but below it. As the shadow rises, its boundary becomes more and more indistinct, and finally vanishes.

Particles of haze just above the blue shadow are illuminated by solar rays which are almost tangent to the earth's surface, and which have passed through a great depth of atmosphere. They are therefore red—a red which is not produced by atmospheric dispersion, but by atmospheric selective absorption; the red of the setting Sun. Particles farther above the arch are illuminated by rays which have traversed a shorter path through the atmosphere, and are therefore yellow—the yellow of the Sun a short time before sunset; and from the red just outside the arch, through yellow, to the colorless sky above, there are all possible gradations.

The colors naturally vary in brightness with the atmospheric conditions, but their order is always the same. JAMES E. KEELER.

LICK OBSERVATORY, Mount Hamilton, California.

Observations of the Leonids.—This report which I send you may not be of much value, coming from an amateur observer, but I will make you one. I began my observations Nov. 12, working with the Harvard observers, and between the hours of 11 and 4 counted and recorded 37. They were not very bright, between 1 and 3rd magnitude. There were three very bright ones. The first, at $11^h\ 20^m\ 15^s$, flashed across the sky, starting from about 5 degrees of the

radiant and dropping down behind the horizon, it showed a disk and left a train for fully a minute. The last two, appearing at $2^h\ 52^m\ 3^s$ and $2^h\ 57^m\ 49^s$, followed the former's example.

THE LEONID RADIANT OF NOV. 12-13, 1898, CHARTED BY W. C. MILLS, BOSTON, MASS.

Nov. 13 was cloudy.

Nov. 14 I recorded and charted 136, all Leonids. There was not one of any special value. Following are the observations for the two nights:

Nov. 12.			Nov. 14.		
h	h	No. Meteors.	h	h	No. Meteors.
11 to	12	7	11 to	12	35
12 "	1	3	12 "	1	30
1 "	2	8	1 "	2	26
2 "	3	9	2 "	3	20
3 "	4	10	3 "	4	25

BOSTON, Dec. 29. M. C. MILLS.

Observations of the Leonids.—Nov. 14, 1898.—The observations were made under unfavorable conditions for the most satisfactory results. Clouds interfered with observations on the night of Nov. 13, and on the evening of the 14th it cleared. Though being on guard this latter night, it was, nevertheless, decided to make notes and plot the paths of at least a few shooting stars, between the hours of walking post. The sergeant of the guard called me at $12^h\ 30^m$ to go on post, and as it is a light artillery post it was mostly in covered stables, with a few horses in a shed near by, and it was necessary to walk out to the shed every ten or fifteen minutes and besides at the end of every beat I would be at the end of the stables in which was an open door, and this afforded an opportunity to note how many stars were shooting, though no notes could be made.

THE LEONID RADIANT OF NOV. 14-15, 1898. CHARTED BY W. E. SPERRA, FORT ADAMS, R. I.

I came off post at $14^h\ 30^m$, and then I made an effort to record some of the brighter ones at least. It was necessary for me to stand outside of a window of

the guard-house through which the light shone, and with the chart published in No. 59 POPULAR ASTRONOMY, watch and note book in one hand and a pencil to mark their paths on the chart in the other, I succeeded in marking approximately the paths of twenty shooting stars, and of which fifteen are undoubtedly Leonids.

Though the observations were made under the most discouraging conditions several peculiarities were noted. Not any much brighter than a standard first magnitude star were seen, and nearly all of the meteors appeared in the north, northeast and east portions of the sky, and none higher than the altitude of the radiant. At $12^h\ 30^m$ when I went on post they nearly all made their appearance in the neighborhood of and below Polaris, later they extended to the northeast and then east. There were about two maximums, one at the last named hour, and the other about 16^h, when faint ones were exceedingly numerous. My view, while registering the paths, was toward the radiant or rather it covered the north, northeast and east portions of the sky and as I had noticed while on post that the meteors were appearing in the north and northeast portions of the sky only, I would occasionally step out to note if there still continued to be a scarcity in the south and west portions of the sky, and not a single meteor from the Leonid radiant appeared in that portion of the sky or in the part near the zenith.

Perhaps in all 150 to 200 meteors were seen from $12^h\ 30^m$ to $16^h\ 45^m$, and about four-fifths were Leonids or from radiants in the immediate vicinity. The apparitions of the Leonids lasted for only a moment, which limited the number I could plot and also the accuracy of the plotted paths, yet the paths of fifteen extended backward meet within the group of the Sickle. Another thing that vitiates the value of the results is the shortness of the observed paths. Below are brief notes of the apparitions recorded on the chart. The times are Eastern Standard.

	h	m	
1.	12	52	Near κ Ursae Major; trail about 4° long; 2d mag.
2.	2	58	Trail over 10° long; color whitish, bright as Procyon.
3.	2	59	In Coma Berenices and same as (2).
4.	3	9	Trail about 8° long; color whitish; bright as γ Leonis.
5.	3	24	Near Θ Leonis; trail about 7° long; color yellow; bright as α Leonis.
6.	3	28½	Near π Virginis; trail about 5° long; color greenish; bright as δ Leonis.
7.	3	30	In Leo; trail about 2° long; 4th mag
8.	3	33½	From η Ursae Majoris to Ξ Bootis; 3d mag.
9.	3	54½	Near β Virginis; trail about 4° long; color yellowish white; 3d mag.
10.	3	59	In Crater; trail about 7° long; color whitish; 2d mag.
11.	4	1	Near η Bootis; trail about 1½° long; color red; lasted several seconds; 1st mag.
12.	4	9	In Monoceros; trail about 10° long; color yellowish; 1st mag.
13.	4	20	Appeared in northern Virgo; trail 5° long; 2d mag.
14.	4	23	Near ξ Puppis; trail 8° long; color whitish; 2d mag.
15.	4	24	Near Ξ Ursae Majoris; trail 6° long; color yellowish white; 2d mag.
16.		28	Near γ Virginis; trail 4° long; 3d mag.
17.		43½	In Sextans; trail about 13° long; color whitish; 1st mag.
18.		44½	Near α Hydrae; trail 10° long; 2d mag.
19.		46	In Monoceros; trail 5° long; 4th mag.
20.		46½	In Leo Minor; trail 3° long; slow moving; 1st mag.

FORT ADAMS, R. I. WM. E. SPERRA.

A Cloud Phenomenon at Omaha.—At about half past seven on the

morning of Decemcer 11, while a gentle breeze was blowing from *WSW*, the thermometer being + 15° F. and the barometer 28.70 in., a peculiar cloud phenomenon was noticed. It consisted of a narrow strip, from one-half to a whole degree in width, stretching across the sky from the point at which the Sun rose to the opposite point of the horizon. Sighting along a straight edge proved the strip to lie all in one plane, and to form the perfect half of a great circle of the sphere. Its highest point was 4½ degrees above the horizon in azimuth *N* 20° *E*. There was no other cloud in the sky until some time in the afternoon, when banks began to form under the strip and at the opposite part of the horizon. The strip slowly shifted its position until by noon its point of intersection with the horizon had moved from *ESE* to *E* and it continued to move slowly in the same direction until dusk but its inclination remained unaltered all day.

WM. F. RIGGE, S. J.

The Total Eclipse of the Moon at Omaha.—The total eclipse of the Moon of Dec. 27 could not be observed on account of the Moon's low altitude and the clouds and smoke which obscured that portion of the sky. However, this much could be determined beyond doubt, that a considerable amount of Sunlight must have fallen upon the Moon during at least the last half hour of totality because in spite of the clouds and smoke the whereabouts in the sky of its disk could be plainly seen. I need scarcely add that my students were very much disappointed since every one of them had made a careful graphic construction of the eclipse. WM. F. RIGGE, S. J.,

CREIGHTON COLLEGE OBSERVATORY
Omaha, Neb.

Ahaz and Dials.—The action of the gnomon or straight edge of a sundial depends on the latitude of the place where the dial is used,—not on the latitude for which it may have been made. Jerusalem is about eight degrees north of the tropic of Cancer; and the Sun, at noon, on the day of the summer solstice, will be about eight degrees south of the zenith. If a person in any place north of the aforesaid tropic, on that day or any other day of the year, will set up two sticks at any convenient distance apart, and arrange them in line with the Sun as it rises above the horizon, he will find that the Sun will move away from the line of the sticks, continuously toward the right all day long. Consequently, the shadow of any object will also move continuously to the right, if the eye looks from the object in the direction in which the shadow falls. It makes no difference whether the edge which casts the shadow is perpendicular to the horizon, on leaning in any direction, and at any angle whatever. Further, the surface on which the shadow falls, may be a horizontal plane, or one tilted in any direction and at any angle; as it may be the convex or the concave side of a spherical or other curved surface. It is simply a physical impossibility for the shadow to reverse its direction except within the torrid zone.

J. MORRISON.

The Dial of Ahaz —Dr. Morrison's ingenious explanation of the going back of the shadow of the dial of Ahaz, page 537 of Vol. VI, seems to be eliciting various sorts of comments (Volume VII, page 51 and Vol. VII page 14) so I trust I may also be pardoned for alluding to it as I only wish to know to what extent the author is willing to acknowledge priority for the suggestion to the "method of demonstrating how the shadow of a style on a Sun-dial may go backwards

without a miracle" first given, I believe, by Nonius the Portuguese astronomer who lived from 1492 to 1577. His demonstration is given on Page 321 of Vol. III of Hutton's edition of Montucla's Ozanam's ***Recreations in Mathematics and Natural Philosophy***, published in London in 1803, a well-known and widely distributed work in four volumes. Surely there is "nothing new under the Sun," not even in the shadow thereof!

HERMAN S. DAVIS.

The Sun-Dial of Ahaz.—As was to be expected, my paper on the Dial of Ahaz has called out a large number of critics from all portions of the United States Canada and England. The great majority of the criticisms are decidedly favorable and of the few adverse ones I propose to reply to three only, viz.: those of Rev. Dr. Talmage, of Washington, Professor Swift, of Echo Mountain Observatory, California, and Mr. Saunders, of England. The first two belong to those who actually believe that black is white and white is black, if the Bible says so; they contend that the Sun did really go back or in other words that the Earth stopped in its diurnal motion, revolved backwards through an angle of ten degrees and then resumed its ordinary course. The first quotes II Chron. 32 Chap. verse 31 to prove that the phenomenon was observed at Babylon and refers to Herodotus to show that it was also noticed in Egypt.

The passage in II Chron. proves nothing of the kind but rather the contrary. The fame of the Hebrews and especially of their prophets and other great men such as Joshua, extended far and wide among the neighboring nations and the Babylonions no doubt heard of the alleged miracle of the Sun-Dial and accordingly sent "ambassadors to enquire about the wonder that was done in the land." If the phenomenon had been observed in Babylon, the scientific men there were fully competent to investigate the matter according to the light they had, but they would never have sent experts to Jerusalem to enquire of the ignorant and superstitious Hebrews who never devoted themselves to astronomy or to any of the other physical sciences. I also fail to find a single line in Herodotus to substantiate the statement that it was observed in Egypt or anywhere else. Nevertheless the phenomenon may have taken place in localities other than Jerusalem, but if so, it was because the dials were *inclined* ones like that of Ahaz; it would be absolutely impossible north of the Tropic of Cancer with an ordinary *horizontal dial* or with a *gnomon*. The first critic tells us that Ahaz invented the dial which is certainly not the case for dials were in use in India and China centuries before the time of Ahaz. In the latter country portable dials with magnetic needles attached, were quite commmon. Again neither of these critics distinguishes between a *dial* and a *gnomon*: the former is portable and constructed for a certain latitude and if erected at a place other than that for which it was constructed, it must be adjusted to the latitude of the latter place as shown in my paper, while a gnomon is simply a perpendicular post or pillar erected on a horizontal plane (it may be only a level field) with a series of circles or stakes to mark the extremity of the shadow at certain hours of the day; it was a very rude construction and could never furnish more than a rough approximation at the best. While these gentlemen have considerable to say in a general way—but which really possesses no merit—they carefully abstain from criticizing the mathematical part of my paper—that portion is impregnable and cannot be successfully assailed.

With regard to my third critic, Mr. Saunders, I have to say that equation (2) viz.:

$$\tan \theta = \sin \varphi \tan h$$

does not admit of the treatment which he proposes for the reason that θ has not

a series of maxima and minima values The azimuth of a circumpolar star of the Sun or a star when it culminates *north* of the zenith does admit of two maximum values at the elongations and two minimum values when on the meridian. Equations (2) and (5) exist at the same time and therefore when h is eliminated between them Eq. (8) obtains. As regards the shadow I may remark here what I deemed unnecessary in my paper, viz.: that the style was a right angled triangle—the usual form or shape with the hypothenuse pointing to the pole—and representing its height by a it may be considered to consist of an infinite number of perpendicular laminæ whose lengths vary from 0 to a and therefore the shadow of any point of the hypothenuse will have a locus similar to that of the vertex of the style which I have shown to be a conic section. The line of shadow CE (see diagram) therefore revolves around the point C as a centre. Moreover the calculation of θ need not extend beyond the 6 o'clock hour line or 90° at which time h is also equal to 90°, because the 7 o'clock P. M. hour line is simply the extension of the 7 o'clock A. M. line. Since the tangent of 105° is numerically equal to the tangent of 75°. In conclusion, I maintain that the going back of the shadow on the Dial of Ahaz was no miracle but an ordinary astronomical phenomenon which can occur under certain conditions here in Washington as well as in Palestine.

J. MORRISON, M. D.

1757 P. St. N. W., WASHINGTON, D. C.,
Jan. 12, 1899.

Comet 1862 III.—I have read Professor Hall's last letter in the January number of POPULAR ASTRONOMY, where he asks why, after 36 years, I should say the comet of 1862 had a tail which I said nothing about it at the time. He and Professor Tuttle make a great ado over the matter for it constitutes their entire stock in trade, hence the tenacity with which they clirg to a shadow.

On reflection, I think I should have done so in my first letter. Even if a little late, he will see that I have not attempted to prove too much. When I discovered the comet 36 years ago, I was a novice in observational astronomy and was so undecided as to whether it was a tail or only an imaginary one, I thought it best to say nothing, in order not to lay myself liable to ridicule in saying I had seen a tail which nobody else could see. During my long work on comets and nebulae of every grade of brightness and faintness and never seeing a tail-like appearance to the latter, and on several occasions seeing the same appearance to the former, I have for many years been more and more convinced that the supposed tail to the 1862 comet was not imaginary but real, and hence the announcement, which from inexperience I dared not affirm at the time. Why need it appear so very strange that it had an insipient tail when not long after it had one on one night 25° long?

Now I am done with this comet controversy except to say I have expressed no desire for posterity to consider me as being the discoverer, but only that I discovered it three days before Professor Tuttle did, and to defend my good name against the foul aspersion that I was promulgating a falsehood, which with me never goes unrebuked.

Professor Denning, in his unbiased letter, naively remarks that "I have gained so many honors in searching for comets and nebulae, that it will make little difference whether or not the comet is deducted from his (my) claims."

My rejoinder to his remarks on the intra-mercurial planet question, which he injudiciously calls Vulcan will be reserved for another occasion. LEWIS SWIFT.

LOWE OBSERVATORY, Echo Mountain, Cal., Jan. 5, 1899.

Telescope Making in New York.—Several years ago Mr. Charles Lembke, the present head of the firm of Gall & Lembke, located for more than a generation at No. 21 Union Square, New York City, entered into an arrangement with John Byrne, the pupil and successor of Henry Fitz, the earliest American telescope maker, by which Mr. Byrne was henceforth to furnish object-glasses exclusively for telescopes turned out at the shop of Gall & Lembke.

This combination has had most happy results in bringing the work of Mr. Byrne into the hands of an enlarged circle of both amateur and professional astronomers.

No attempt is made to turn out telescopes of gigantic size, calculated only for the use of specialists in a few great observatories, but the object in view is to furnish to those desiring instruments of moderate dimensions the finest products that skill and knowledge can offer, at prices which need not be prohibitive to any lover of the stars.

Some of Byrne's finest masterpieces—Instruments that their owners would hardly part with at any price—are between four and six inches aperture, usually of short focus (for convenience of handling as well as for brightness of image) and with exquisite definition. The manner in which one of these short-focus object-glasses cuts out the disk and belts of Jupiter, or the rings of Saturn, and splits close and difficult stellar pairs, can only be fairly appreciated by one who has compared their work with that of inferior glasses.

Recently, Mr. Lembke has presented to the Astronomical Department of the Brooklyn Institute a telescope with an object-glass of 8 inches aperture, made by Byrne. This glass will soon be mounted in Brooklyn. The beauty of its star images is said to be beyond praise. It more than answers every test applicable to an instrument of its size, and an enthusiast who has looked through it says: "The sight of the *debilissima* in Lyra shining as steady as little moons between the glittering pairs of the Epsilons is a thing to make an appreciative astronomer clap his hands with sheer delight."

It must be a pleasure to all who are interested in the progress and spread of astronomy to learn from Mr. Lembke that within the past year there has been a marked increase in the popular demand for telescopes of first-class quality, ranging in aperture as high as six and seven inches. The majority of these glasses have gone into the hands of amateurs, who wish to see for themselves some of the wonders and beauties of starry space.

Correction.—In Mr. Denning's paper on "Who discovered the comet of the Perseids?" in our last number, page 16, a few words were unfortunately omitted. The second paragraph should read "La Lande discovered Neptune half a century before the researches of Le Verrier and Adams enabled Galle at Berlin to telescopically discover it and Challis to afterwards pick it up in the Northumberland telescope at Cambridge."

Observations of the Variable Star Mira Ceti. During the past apparition of a maximum of the variable star, *o* Ceti, about fifty observations on different nights were obtained, on many nights several estimates were made at various hours, the estimate considered most reliable, only being recorded. My first observation for the season was on September 17th when I was rather surprised at the brightness of the variable, it rapidly increased and was apparently at a standstill from September 29th to October 5th with possibly a trace brighter on October 4th and 5th. The following are the results of my observations in detail:

Date. 1898.	Central Time.	Magnitude.	Remarks.
Sept. 17th	11:00 P. M.	3.6	Fully as bright as Gamma Ceti.
" 19th	11:00 "	3.4	Brighter than γ Ceti.
" 20th	10:00 "	3.3	Distinctly brighter than γ Ceti tonight.
" 23rd	11:00 "	3.0	Much brighter than Gamma.
" 24th	10:45 "	2.8	About equal with β Arietis.
" 25th	10:10 "	2.7	Moon past first quarter, but a trace inferior to α Ceti tonight.
" 26th	10:50 "	2.8	Does not seem as bright tonight.
" 27th	10:30 "	2.8	
" 29th	10:00 "	2 68	Moon full, estimated as being exactly equal with α Ceti.
" 30th	10:30 "	2.68	
Oct. 1st	10:15 "	2.68	Nearly full Moon near.
" 4th	10:00 "	2 6	Good observation, no Moon, a trace brighter than α Ceti.
" 5th	10:00 "	2 6	
" 6th	10:00 "	2.8	Seems certainly fainter than α Ceti and almost exactly same as β Areitis.
" 8th	10:30 "	2.75	Very good observation, dark night, Mira fainter than α Ceti and trace brighter than β Areitis.
" 11th	10:00 "	2.8	Same as β Arietis.
" 13th	10:00 "	2.8	" " " "
" 15th	10:00 "	2.7	Sky hazy. Mira appears brighter.
" 22nd	10:00 "	2.7	Moon first quarter.
" 23rd	8:30 "	2 7	
" 25th	10:00 "	2.8	Mira seems equal with β Arietis.
" 30th	9:30 "	2.7	Moon bright, a good observation, Mira is a little brighter than β Arietis.
Nov. 1st	10:00 "	2.8	Bright moonlight.
" 2nd	9:30 "	2.9	Mira fainter than on last night.
" 3rd	8:30 "	3.0	Observation taken before Moon rose.
" 6th	10:00 "	3.0	Observation good.
" 7th	10:30 "	3.0	Hazy sky.
" 8th	10:30 "	3.0	" "
" 9th	10:30 "	3.2	Good observation. Much fainter than β Arietis.
" 10th	10:00 "	3.1	Mira and τ Ceti alike.
" 11th	10:00 "	3.2	
" 13th	9:30 "	3 3	Good observation, night dark.
" 14th	10:30 "	3.4	A little brighter than Gamma Ceti.
" 15th	10:30 "	3.3	
" 16th	10:00 "	3.4	Slight haze.
" 25th	10:45 "	3.6	Brilliant moonlight, almost equal to Gamma.
" 26th	——	3.8	" " " " " "
" 29th	——	3.8	Seems fainter than γ Ceti.
" 30th	8:00 "	3.8	" " " " "
Dec. 1st	10:45 "	4.0	Slightly brighter than Delta Ceti.
" 3rd	8:00 "	4.0	Good observation, night dark.
" 4th	10:30 "	4.1	Same as δ Ceti.
" 7th	10:30 "	4.1	" " "
" 10th	8:00 "	4.5	Good observation. Much fainter than δ Ceti.
" 13th	10:00 "	4.4	Same as χ_1^2 tonight
" 14th	9:00 "	4.4	" " " "
" 15th	8:20 "	4.7	
" 26th	7:30 "	5.0	
1899.			
Jan. 1st	8:00 "	6.0	Careful observation with 4 inch telescope.
" 13th	9:00 "	6.8	" " not as bright as 71 Ceti.
" 15th	9:30 "	6.6	Seems to be a trace brighter than 71 Ceti.

Comparison stars used, γ Ceti = 3.60 α Ceti = 2 68 β Areitis = 2.8
δ Ceti = 4.13 χ_1^2 Ceti = 4.4 71 Ceti = 6.5 α Pisces = 4.0
Nu Ceti = 4.9

ALTA, IOWA, Jan. 17th, 1899. DAVID E. HADDEN.

New Elements of the Planet 1898 DQ.—The following elements of the planet DQ have been computed from observations of Aug. 15, Sept. 27, and Nov. 11. The interval included is 88 days. In this time the planet described a heliocentric arc of about 37°, or a little more than a tenth of a revolution.

Epoch 1898 Aug 31.5 Gr. M. T.

$M = 221°\ 33'\ 29''.1$
$\omega = 177\ \ 41\ \ 21\ .0$
$\Omega = 303\ \ 30\ \ 19\ .2$
$i = \ 10\ \ 49\ \ 33\ .5$
$\phi = \ 12\ \ 52\ \ 16\ .1$
$\log a = 0.163710$
$\mu = 2015''.773$
Period 642 929 days = 1.76 years.

W. J. HUSSEY.

A Gigantic Artificial Moon.—Under the above heading the *Scientific American* of April 9, 1881, urged the attendance of its readers upon an exhibition at Steinway Hall, New York city, of a model of the Moon 16 feet in diameter. The article closed by expressing the hope that the model might ultimately find a permanent abiding place in "some of our public institutions." After a lapse of nearly eighteen years, this wish has been realized, and the model is now permanently installed at the Field Columbian Museum, Chicago. Students of science, whether casual or professional, may well rejoice over the opportunity thus afforded them to become familiar with the physiography of the Earth's satellite with but a tithe of the labor and equipment required to study it by means of a telescope. What was said of the model by the *Scientific American* then is true still: "It is by far the largest, more elaborate, and expensive portrait of the Moon ever made, and, seeing that it was constructed for and under the immediate direction of one of the most eminent selenographers, Dr. Schmidt, Director of the Observatory at Athens, Greece, we may safely accept it as a faithful portrait." The model is a hemisphere 19.2, not 16 feet in diameter. It is made up of 116 sections; 15° in length by 15° in breadth, which serve to mark upon the surface paralleis and meridians. The horizontal scale is 1 : 600,000, the vertical 1 : 200,000. The elevations are therefore exaggerated but three times, a much smaller increase than is usually necessary to bring out features of detail on relief maps of the Earth's surface. By means of this scale the various features of the Moon's surface have been accurately and vividly portrayed. The extraordinary volcanic activity which our satellite has undergone impresses one at the first glance, while the mountains, plains, cliffs, and chasms, surpassing in grandeur anything to be found upon the Earth, are vividly shown.

Here, for instance, are Copernicus with its vast crater 46 miles in diameter, its interior marked by terraces formed by huge landslips which took place along the mighty ramparts; here are the awful chasms, a mile wide and 100 miles long, radiating from Triesnecker; the magnificent group of Theophilus, Cyrillus and Cathrina, with craters 60 and 65 miles in diameter merging into one another; the walled plain Schickard, 153 miles in diameter with ramparts several miles in height; the "thin cheese" of Wargentin, apparently a crater that has been filled with lava to the brim which remains in place cold and hard; the mighty "seas" of Oceanus Procellarum and Mare Crisium, which are in reality vast plains, covering areas of 90,000 and 78,000 square miles; and all the other objects to the number of twenty thousand, which it has been the labor of astronomers from the earliest times to measure and describe. Later discoveries are not likely to add

much detail necessary to the completeness of such a model, for the features sufficiently large to be shown by it have been agreed upon by astronomers for many years. The impression gained of the condition of the Moon's surface by looking at the model is that it is a scene of utter desolation and ruin—a globe without life or comfort for beings such as man. This is undoubtedly what one would find could he make a trip to the Moon itself, and a view of this model is perhaps the best substitute for such a journey which has yet been devised.

Mr. Lewis Reese, of Chicago, was the donor of the model to the museum.—*Scientific American, Jan. 28, '99.*

The Sun-Dial of Ahaz.—In the last issue of POPULAR ASTRONOMY I find a contribution from Professor Swift wherein he calls down Dr. Morrison for his explanation of the alleged miracle concerning the dial of Ahaz. It has become evident that these men accept as a fact this ancient story of a time when miracles hardly created a ripple of surprise.

I do not desire to call in question their methods or their conclusions so much as I do to remark on the fact that men of science of their standing should, or do, accept such a record as a truth of history.

In order to establish such an occurrence as a fact, a miracle, an "event of tremendous import" as Professor Swift terms it, surely the evidence should be unimpeachable, and even then one would be safer to conclude that all the spectators of the affair were deceived than he would to conclude that God "changed the index of refraction" as Professor Swift suggests in order to accomplish the "Sign."

The fact is that such evidence as we have for this occurrence would not warrant a jury in convicting for petty larceny. Neither, the composer of the Book of Kings or of Chronicles is known and their work was written long years after Hezekiah's reign even in the Babylonian Captivity.

The brief mention in the Book of Isaiah proves nothing for we know beyond question that there were at least *two* authors and we do not know how many more trifled with it as they copied it.

The Hindoos have a saying that, "though you soak a dog's tail in oil and keep it in splints during a year, still you will not take the curve out of it." The religious curve given to the childish mind is rarely taken out. The deformity will be manifest ever afterwards. It is particularly discouraging to find astronomers entertaining such unworthy beliefs. They at least ought to have some proper comprehension of the magnitude of a miracle that turns backward the shadow of a Sun dial! No wonder that Professor Swift calls it "an event of tremendous import."

"An undevout astronomer must be mad" runs the old saying, because he can in some adequate measure realize something of the infinite grandeur of the universe and form some rational conception of the Infinite Wisdom "that sitteth on the circuit of the heavens and calls the stars by name." But here it turns out that an astronomer who is a veritable sleuth-hound of the skies, running down comets that venture within his keen range, and still believing in a God so small that he piles up the atmosphere in the Sun's path to twist the light rays in order to pacify a weak and unworthy king. No good ever came of it. The "event of tremendous import" was out of all proportion to the thing to be accomplished. It was shooting mosquitos with cannon balls.

R. R. MCLEOD.

974 Mass. Avenue, CAMBRIDGE, Mass.

Dr. G. W. Hill's Courses of Lectures at Columbia College, in New York City, have been in progress since October, 1898. The University course in Celestial Mechanics is being given in the astronomical lecture room on Saturdays at 10:30 A. M. Its character is indicated by the following divisions:

1. General equations of Dynamics.
2. Derivation of gravitation from the phenomena.
3. Differential equations of a system under the action of gravitation.
4. The theory of elliptic motion.
5. Perturbations as variations of coördinates.
6. Perturbations as variations of the elliptic elements.
7. Hansen's method.
8. Delaunay's method.
9. Gyldèn's method.
10. Development of the perturbative function.
11. Secular perturbations in particular.
12. The Lunar Theory in particular.
13. The Theory of satellites.
14. General considerations on the stability of motion of planetary systems.

Dr. Geo. W. Hill began his course of lectures on Celestial Mechanics on Oct. 15th. In this course Dr. Hill deals with the subject historically. In the six lectures so far given he has shown how Ptolemy explained and computed the positions of the Sun, Moon, Mercury and Venus, and has compared Ptolemy's results with the modern. Dr. Hill is giving also an advanced course in Celestial Mechanics.

Nebulosities Exterior to the Pleiades. We copy from *The Observatory* (December, 1898,) the following remarks made by Dr. Isaac Roberts before the Royal Astronomical Society, Nov. 11, 1898. This most remarkable setting forth of results which Dr. Roberts could not secure (and therefore no one else could) must have been highly entertaining to the Royal Society. It certainly has been to several American astronomers. Dr. Wilson's article in this number refers to this matter:

"The photographs sent by Professor Barnard, which have just been shown projected on the screen, must be well known to all present; for the contact positives-on-glass made from his original negatives have been exhibited during several months in the library of the society and are still preserved. They have also been extensively published in various periodicals, and yet they seem to be as little understood, from a scientific point of view, now as they were when first presented.

"Speaking for myself I have frequently made very careful examination, and have tried to see in them the merits which Professor Barnard and the casual examiners of them profess to see, which, in effect, is that the stars in the Milky Way are immersed in dense nebulosity, with numerous rifts trending in various directions within it. At the time I first examined the photographs my opinion was that those vast areas of cloud-like matter exhibited upon them were not due to real nebulosity, but to the effects of starlight and atmospheric glare concentrated by a small lens of short focus during many hours exposure to the sky of very sensitive films; but that the star-images, both bright and faint, having their photo discs overlapping or brought by the lens into close proximity with each other, together with diffraction effects and the atmospheric illumination consequent upon these conditions, caused the glare, and gave it the appearance of extensive nebulosity. Besides these causes, there is also the manipulation in copying the original negatives, which intensifies their misleading effects.

"When the photographs were first presented to the society some of the Fellows jumped at once to the conclusion that these wonderful photographs, as they termed them, revealed astounding possibilities in the domain of cosmical physics, and having committed themselves to these ideas they have not, even yet, brought themselves to consider them judicially upon their merits.

"The real nebulosity with which we can deal in the sky is limited, with few exceptions, to relatively small areas, and generally it is not difficult to distinguish it from the large areas of spurious nebulosity which are so extensively shown on these small-scale photographs.

"Referring to the assertions so persistently repeated that there are 'Nebulosities exterior to the Pleiades,' it is disappointing to find that no photographs have been exhibited to the meeting and no evidence produced tending to prove the correctness of Professor Barnard's assertions concerning them; instead of which the meeting is referred to two photographs presented to the society years ago, and to statements made that two gentlemen in America had confirmed the existence of the nebulosity, but no evidence whatever is presented to show that there is reliable data available, as well as the necessary experience, to enable them to form a competent judgment concerning this investigation, which requires exceptional care and experience in dealing with it.

"If the nebulosity really exists why are the proofs not presented? Real nebulosity should, on a photograph, be indisputably recognized by its characteristics when seen by any competent examiner; but in this case repeated assertions are presented, and not a single reliable photograph has been produced to prove the simple facts that scientific men most desire to know.

"I have many times examined the two photographs referred to by Professor Barnard, and have not succeeded in finding upon them any nebulosity such as he describes. Why all this assertiveness and mystery about a matter so simple as producing photographs which would unquestionably satisfy any one whose object is not merely academical discussion, but a desire to arrive at the knowledge of that which is true by demonstration? I have shown before the society my photographs upon which the non-existence of nebulosity of a real character could be detected in the region pointed out by Professor Barnard, though my plates had been exposed during various intervals between one hour and twelve hours respectively; but there is abundant evidence of spurious nebulosity in patches upon some of them, and, in order to make sure of its spurious character, I had carefully compared the original negatives, and also compared positive copies of them made on glass, with the result that the patches shown on any given plate did not coincide in position, extent, or form, with those on the other plates, though there were casual resemblances in parts; whereas real nebulosity, notwithstanding the fact that intervals of many years have elapsed between the epochs when the photographs were taken, always, invariably, and in every detail coincide on all the plates

"I am of opinion that Professor Barnard has been misled by absence of sufficient reliable data in forming his very strong opinion, 'That there can be no doubt whatever' of the existence of the nebulosity to which he refers, the opinion being based upon only one very defective photograph with 10¼ hours exposure; and, further, that any opinion which has been formed concerning very faint suspected nebulosity seen upon a film of high sensitiveness after long exposure to the sky is not worth expressing, nor entitled to any credence, until it has been confirmed by one or two other photographs taken of the region with plates of similar character, and with equal exposure, and afterwards been rigorously correlated with each other by using the stellar images both involved in, and in the light places around, the supposed nebulosity, as fiducial points of reference."

BOOK NOTICES.

An Integral Calculus by Daniel Alexander Murray.—Members of the Cornell mathematical staff are bringing out a series of text-books in Mathematics, some numbers of which have already appeared which are attracting wide and favorable notice. The series is designed, primarily, to meet the needs of students in Engineering and Architecture in the Cornell University, and so many problems have been chosen with this end in view. In presenting rigorous, elementary courses in the various branches, in which the authors have undertaken to prepare text-books, they have also had in mind the wants of general students in these branches of study and they believe their books will be acceptable to this

increasingly large class of students now to be found somewhat generally in the best colleges and universities of this country.

In getting the matter for these new books in shape, the plan has been to prepare a mimeographed edition of each volume to be used for a term, as a text-book in all classes, and the suggestions thus brought out are then considered by the mathematical staff before the book is sent to the press.

The new book now before us in the Cornell series is a copy of Dr Murray's elementary course in the Integral Calculus just published by the American Book Company of New York, Cincinnati and Chicago.

This work is divided into thirteen chapters and covers 288 pages including the index. The first chapter treats of integration as a process of summation of infinitessimals, illustrations of this method being given by the use of the loci of a line and a parabola. After simple analytic proofs, the geometrical principle is stated and illustrated, and then the fundamental theorem is given which is the basis for a knowledge of a definite integral with illustrative examples to fix in mind its general meaning as fully as possible. Chapter second presents integration as the inverse of differentiation. The author makes it clear in the first two chapters that integration should be defined in these two ways to comprehend well the processes the student will need to use as he goes forward in his study of the Integral Calculus. The method of stating and illustrating this means of integration is the one more commonly used. It brings to the attention of the student the ideas of the indefinite integral, the constant of integration, the geometrical meaning of the arbitrary constant and some properties of integrals easily inferred from the notation used. This latter view of integration gives the ordinary method of making the rules for integration. In bringing these two views of integration together as a kind of introduction to the study, the author in our judgment has done one of the best things possible to start a student well in a branch of study that is hard to enter without some such painstaking foundation as that to which we have just now referred. When the student does begin well, comprehending from the first what he is doing, there are few lovers of mathematics who will leave this elegant instrument of investigation until they know much of its power in modern research. These chapters are a specimen of what follows, in the geometrical applications of the Calculus, the study of rational fractions, irrational functions, trigonometric and exponential functions, successive integration, multiple integrals, integral curves and ordinary differential equations.

The geometrical figures are excellent, the typograpical work very superior, and the careful arrangement of the text very satisfactory. We shall adopt it in our special course in the higher mathematics for it is exactly what we want.

A Laboratory Manual in Astronomy has been prepared by Mary E. Byrd, Director of the Observatory, Smith College. Messrs. Ginn & Company, of Boston, New York and Chicago, are publishers. The new book will appear soon.

At present there is a great gulf fixed between the theoretical and practical astronomy of our Observatories and the astronomy taught in our schools. This Manual attempts to apply the methods of astronomers to the more elementary branches of the science, to train from the first the eye, the hand, and the head of the student. To this end, the Manual applies the laboratory method rigorously to astronomy. It puts the teaching of this science as nearly as possible on the same basis as the teaching of other physical sciences, and aims to arouse the interest of students by making direct observation of the heavens the subject for serious study, not occasional diversion.

About one-third of the Manual is devoted to descriptions of home-made apparatus and practical exercises on almanacs, globes and time. The remainder of the book is largely made up of actual observations taken with the unaided eye and with home-made instruments. The reductions and discussions which follow the observations are carried on for the most part by means of the celestial globe and simple processes in arithmetic. The few trigonometrical formulae required may be applied by any one who knows how to take out logarithms.

The Manual is designed as a handbook of laboratory instruction to accompany the study of elementary and general astronomy in secondary schools and colleges.

Elements of Trigonometry by Andrew W. Phillips and Wendell M. Strong. This new book in elementary trigonometry begins by defining and illustrating angles, and then by questions and exercises, the answers to which are not given, the student is expected to become familiar with the concept of angles as they are used in trigonometry. The trigonometric functions "are defined as ratios, but their representations by lines is also introduced at the beginning, because certain parts of the subject can be treated more simply by the line method, or by a combination of the two methods, than by the ratio method alone." The line method is well used on pages 8, 9 and 10 in determining the signs of the functions of various angles which are graphically shown by heavy and light lines and other designations which make the scheme perfectly definite.

In the study of the relations of the functions, those which are fundamental are printed in heavy-faced type, so that the beginner will readily know which are the important ones that on such he may bestow the more careful attention. The tables of exercises are evidently selected by an experienced teacher, for they are graded and full enough for the purpose they are designed to serve.

The angles of a right triangle, the functions of arcs ending at quadrants, those of the supplements of angles, those of any value in terms of quadrants are defined and illustrated by figures very fully. In chapter two is given the solution of the right triangle. After the formulæ for the various functions are made, the authors give models for the student to follow in computing numerical values in the solution of right triangles. One whole page is devoted to the solution of one example to show the form of work to be used when natural functions are employed, and then beside this work, in a parallel column, a method is given when logarithmic functions are chosen in the solution of the same example. This is very important knowledge for the beginner, for he should have from the first the practice of a neat and orderly computer. This kind of skill has in it more value than the ability to obtain results quickly. Logical sequence in approved methods is here well emphasized.

In chapter five, which treats of circular measure, is given a graphical representation of the sine curve and those of all the remaining functions. These curves show very well the periodicity of the functions, even though the student may not yet know the principle, of analytic geometry.

Chapter sixth deals with the computation of logarithms and the trigonometric functions, also De Moivre's theorem and Hyperbolic functions are used in some interesting applications. This chapter is a little severe for beginners who have only a few weeks for the study of this branch. Chapter seven contains fifteen pages of miscellaneous examples, which constitute a thorough review of all that precedes.

Spherical trigonometry is presented in twenty-eight pages and the same general plan is used as that indicated already. The same plan of presenting the figures is employed as that used in the solid geometry in this series. Half-tone cuts accompany the outline figures generally, and so give the student the most definite idea of the projection of a solid which can be shown on the page of a book. Teachers like this feature very much. This book is scholarly, practical and up-to-date in matter and arrangement. Teachers will find four pages of useful reading in the appendix, setting forth the relations of the plane, spherical and pseudo-spherical trigonometrics.